Workshop on Challenges and Innovations in Nanotechnology
18-19 December, Damascus- Syria

Recent advances in the design of nutraceutical nanodelivery systems

Dec, 2019
Damascus, Syria

Prof. Seid Mahdi Jafari

چشم دل باز کن که جان بینی — آن‌چه نادیدنی‌ست آن بینی
دل هر ذره را که بشکافی — آفتابیش در میان بینی

هاتف اصفهانی

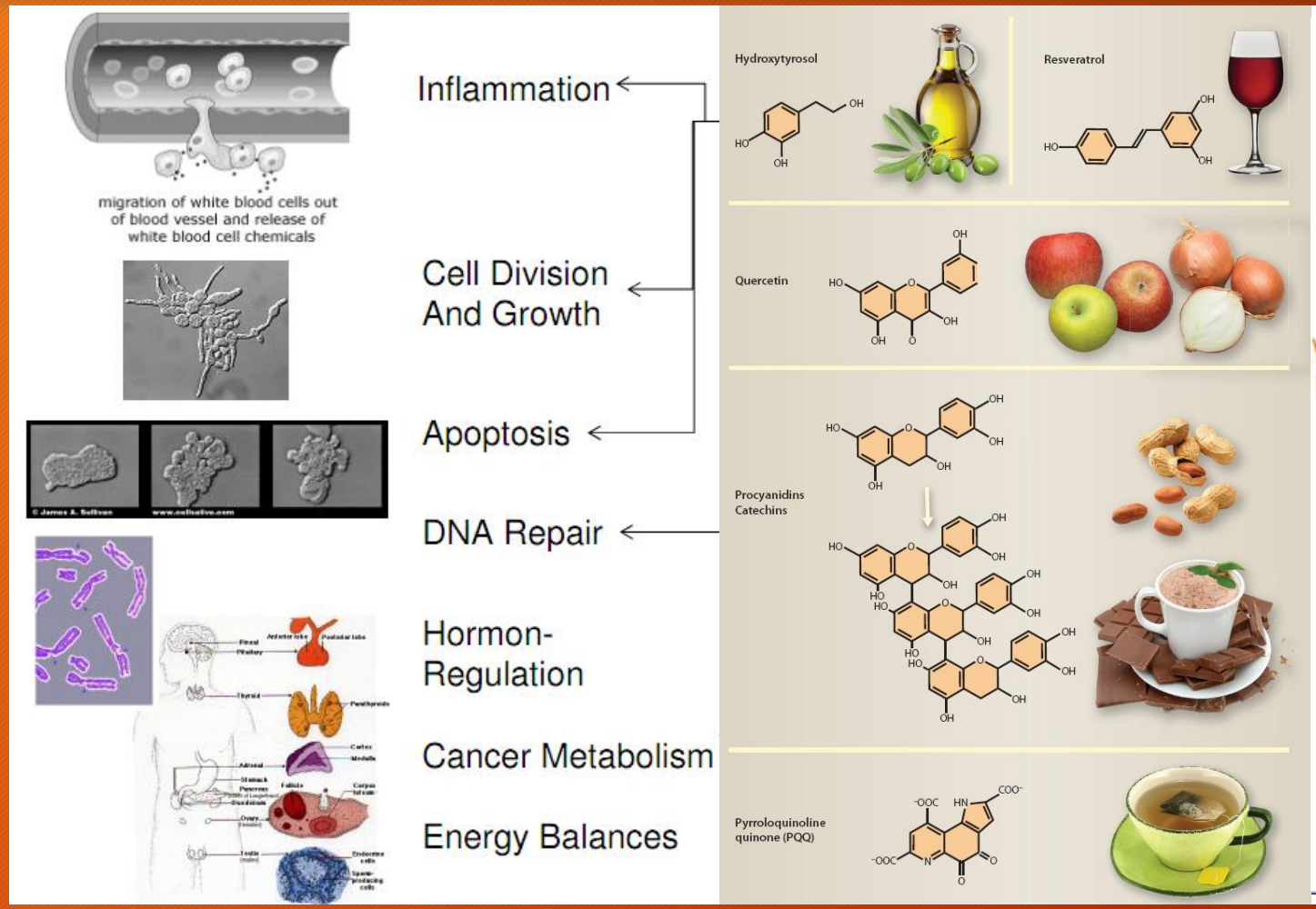
A brief biography

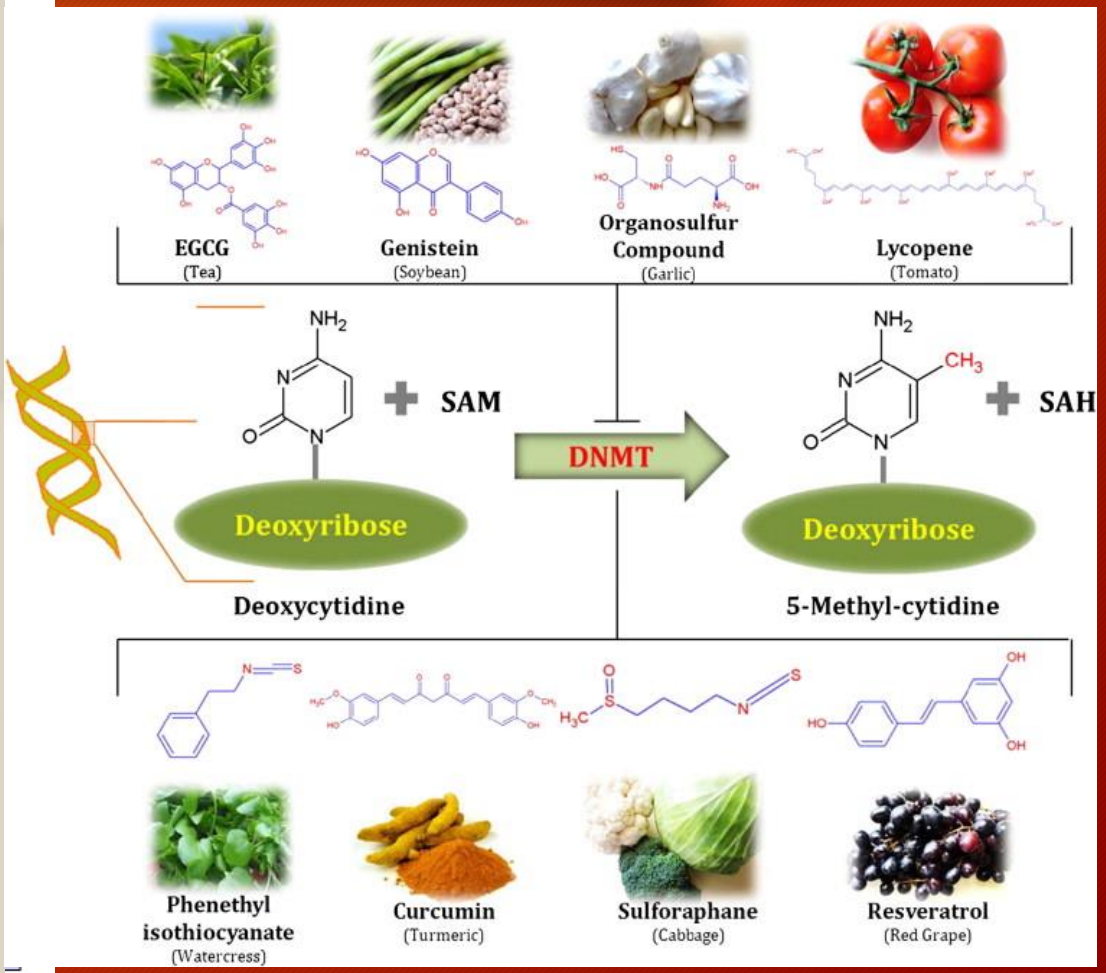
- PhD from the University of Queensland (Australia), in 2007.
- Working on nanoencapsulation of food bioactives for the past 15 years.
- A full professor, and academic member of GUASNR (Iran).
- Publishing >200 papers (h-index= 50) in top-ranked international journals
- Editing 36 books along with 37 book chapters with Elsevier, Springer, and Taylor.
- One of the top 1% world scientists in the field of Biological Sciences (Thomson Reuters, Essential Scientific Indicators); Nov, 2015.
- One of the top national researchers (Iranian Ministry of Science, Research, and Technology); Nov, 2017.
- One of the world's highly cited researchers (Clarivate Analytics, Web of Science); Nov 2018 and 2019.
- Top reviewer in the field of agricultural and biological sciences (Publons, Web of Science); Sep, 2017-2019.

Contents

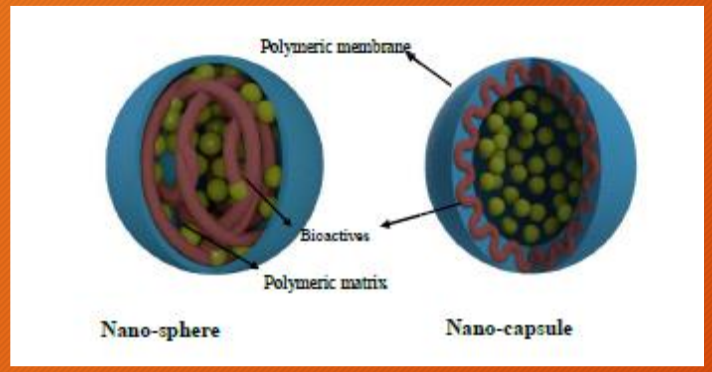
- Bioactive compounds
- Morphology of nanocarriers
- Lipid-based nanocarriers
- Nature-inspired nanocarriers
- Nanocarriers by specialized equipment
- Biopolymer-based nanocarriers
- Surfactant nanostructures
- Chemical polymer nanostructures

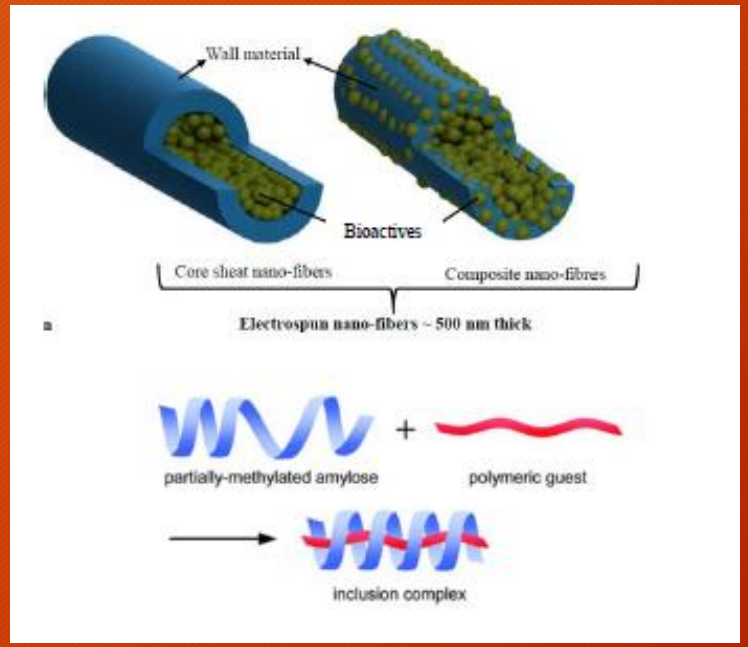
Bioactive Food Ingredients

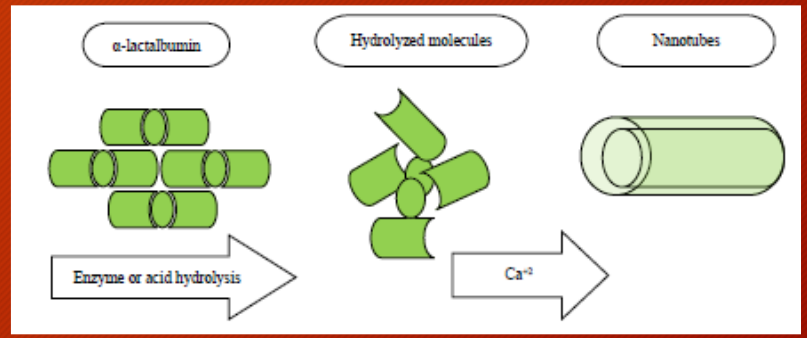


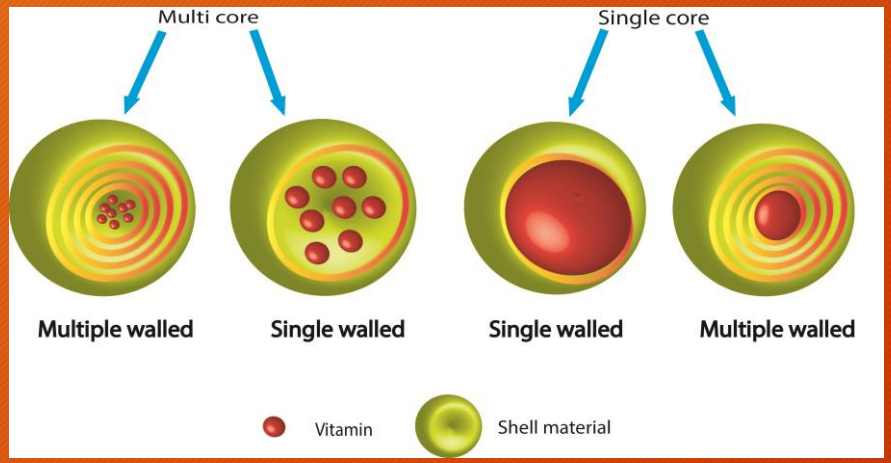


Schematic representation of nanocarriers (1)

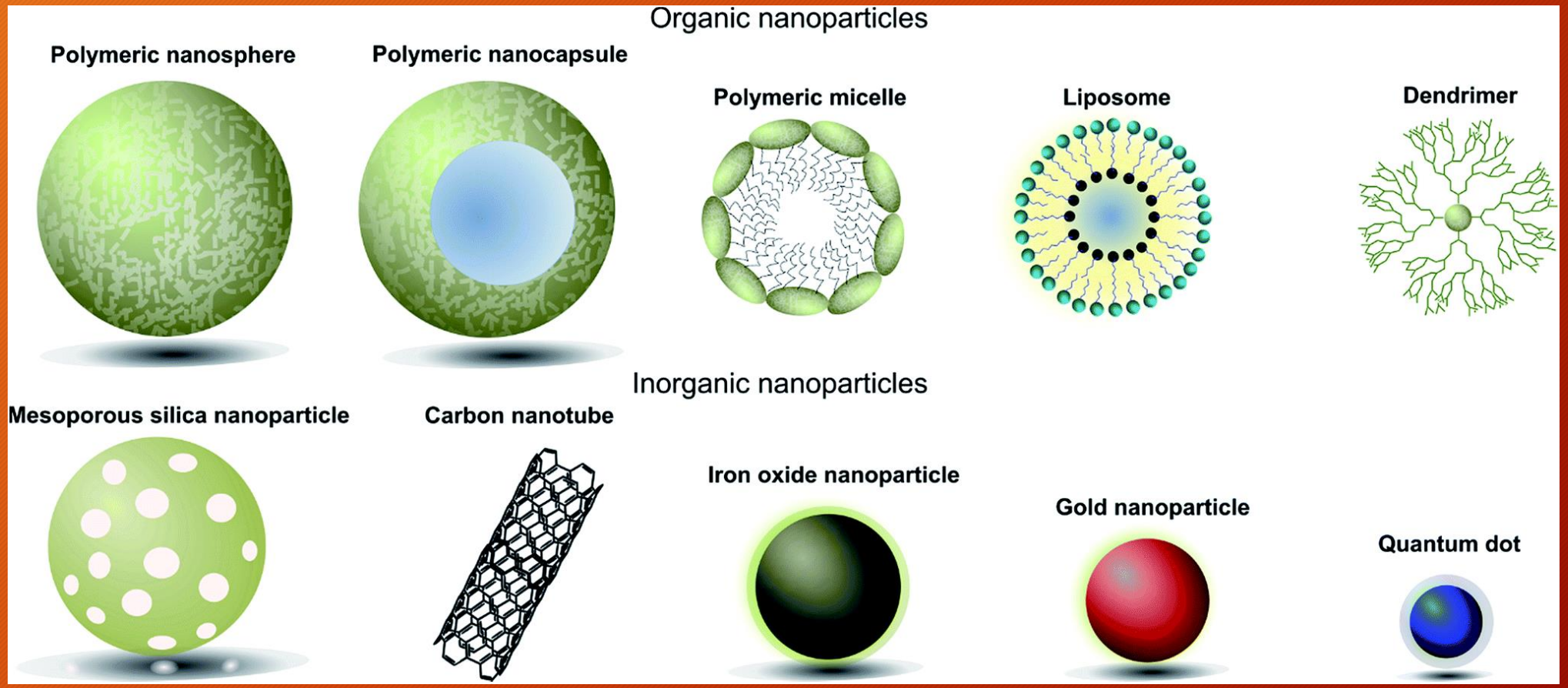








Schematic representation of nanocarriers (2)



A systematic classification of different nanocarriers

applicable to food bioactive ingredients and nutraceuticals

- A. Lipid-based nanocarriers
  - Nano-emulsions
  - Nano-structured phospholipid carriers
  - Nano-lipid carriers
- B. Nature-inspired nanocarriers
  - Caseins
  - Cyclodextrins
  - Amylose
- C. Special equipment-based nanocarriers
  - Electrospinning
  - Electrospraying
  - Nano-spray dryer
  - Micro/nanofluidics
- D. Biopolymer-based nanocarriers
  - Single biopolymer nanocarriers
  - Complexd biopolymer nanocarriers
  - Nano-gels
  - Nanotubes
- E. Miscellaneous nanocarriers
  - Nanocrystals
  - Nano-structured surfactants
  - Inorganic nanocarriers
  - Chemical polymer nanoparticles

A. Lipid-based nanocarriers

Nanoencapsulation in the Food Industry

Lipid-Based Nanostructures for Food Encapsulation Purposes

Volume 2

Edited by

Seid Mahdi Jafari, Gorgan University of Agricultural Sciences and Natural resources, IRAN.

Lipid-Based Nanostructures for Food Encapsulation Purposes, a volume in the Nanoencapsulation in the Food Industry series, reviews recent studies on formulation and evaluation of different categories of lipid-based nanocarriers, discussing how the technology of lipid nanoencapsulation is feasible to be used in industries.

Lipid-based nanoencapsulation systems are mostly used in the food, pharmaceutical, and cosmetic industries. Water-insoluble nanocarriers have the possibility to be scaled up plus the potential of more encapsulation efficiency and low toxicity. This book covers the main types that have been studied and developed in recent years, including nanoemulsions, nanoliposomes, nanostructured lipid carriers, and surfactant nanocarriers.

Key Features

- Brings recent studies on formulation and evaluation of different categories of lipid-based nanocarriers
- Discusses how technology of lipid nanoencapsulation can be used in industries
- Summarizes the practical application of nanostructures from lipid formulations such as nanoemulsions, nanoliposomes, nanostructured lipid carriers and surfactant nanocarriers

About the Editor

Prof. Seid Mahdi Jafari received his PhD from the University of Queensland (Australia), in 2006. He has been working on nanoencapsulation of food bioactives for the past 15 years. Now, as a full Professor, he is an academic member of GUASNR (Iran). He has published more than 150 papers in top-ranked International Journals (h-index=35 in Scopus) and 30 book chapters along with editing 11 books with Elsevier. In November 2015, he was awarded as one of the top 1% world scientists by Thomson Reuters (Essential Scientific Indicators) in the field of Biological Sciences. Also in December 2017, he was selected as one of the top national researchers by the Iranian Ministry of Science, Research, and Technology. Recently in November 2018, he was awarded as one of the world highly cited researchers by Clarivate Analytics (Web of Science).

ELSEVIER
ACADEMIC PRESS
An imprint of Elsevier
elsevier.com/books-and-journals
ISBN 978-0-12-815673-5

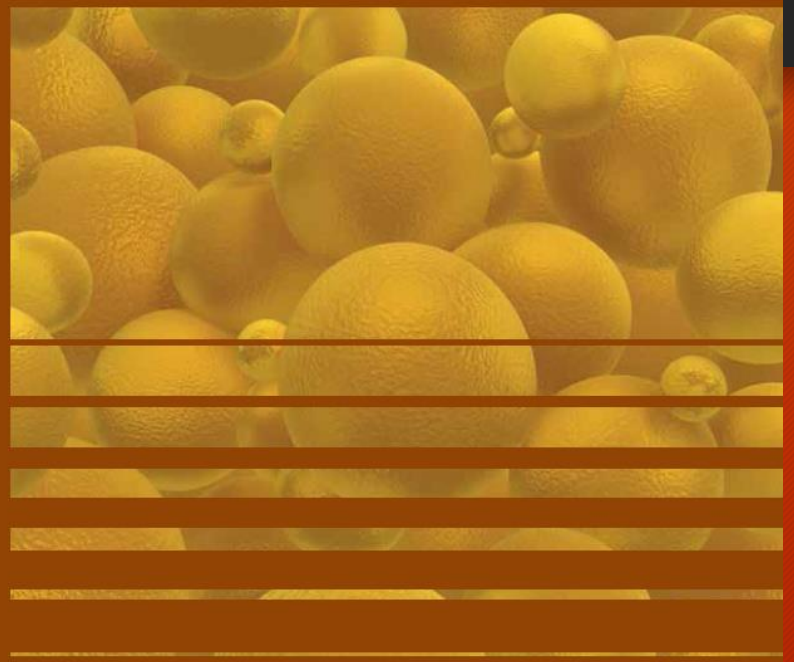
Jafari

Lipid-Based Nanostructures for Food Encapsulation Purposes

Volume 2

ACADEMIC PRESS

Nanoencapsulation in the Food Industry



Volume 2
Lipid-Based Nanostructures for Food Encapsulation Purposes

Edited by
Seid Mahdi Jafari

A. Lipid-based nanocarriers

1. Nano-emulsions

- **Single nano-emulsions**: Oil in Water (O/W); Water in Oil (W/O)
- **Double nano-emulsions**: W/O/W; O/W/O
- **Pickering nano-emulsions**
- **Structural nano-emulsions**: Single interface layer; Double interface layer

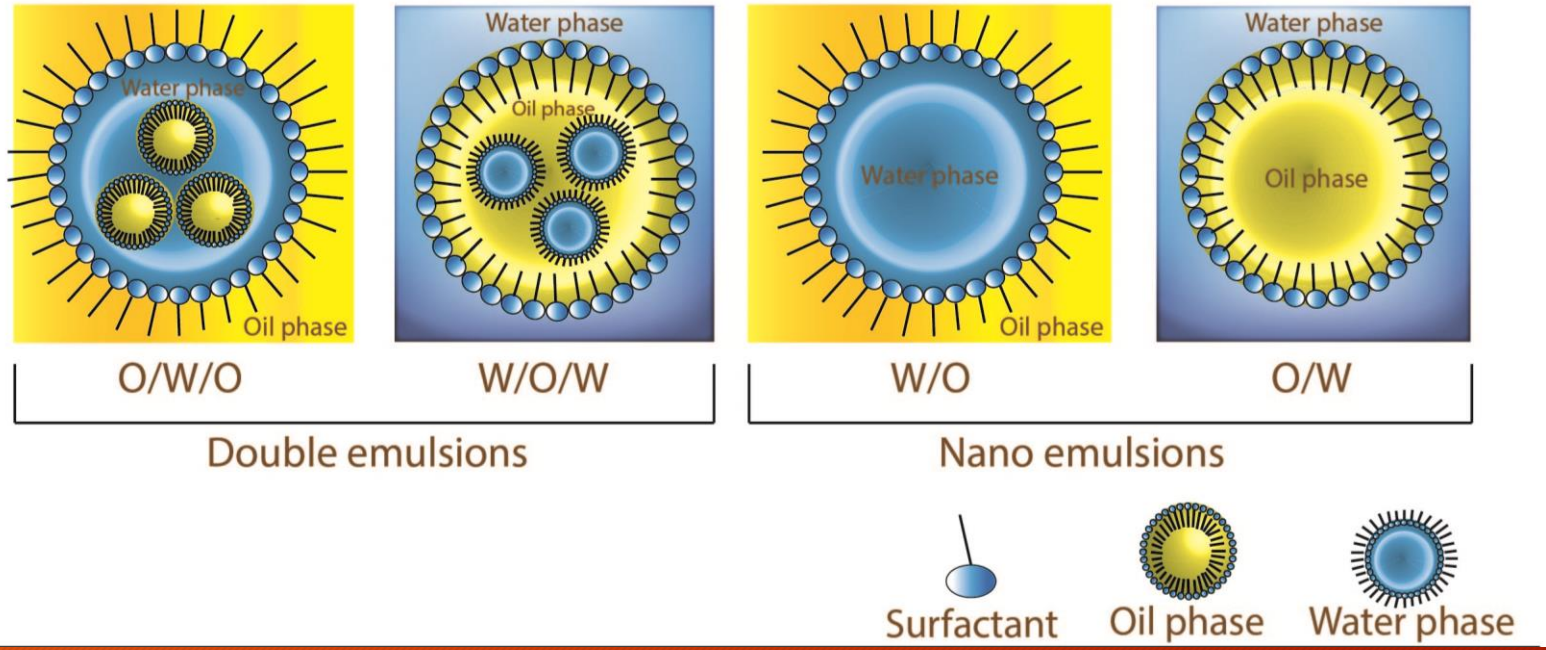
2. Nano-structured phospholipid carriers

- **Nano-liposomes**: Monolayer; Multi-layer
- **Nano-phytosomes**: Monolayer; Multi-layer
- **Structural nano-liposomes/phytosomes**: With coatings

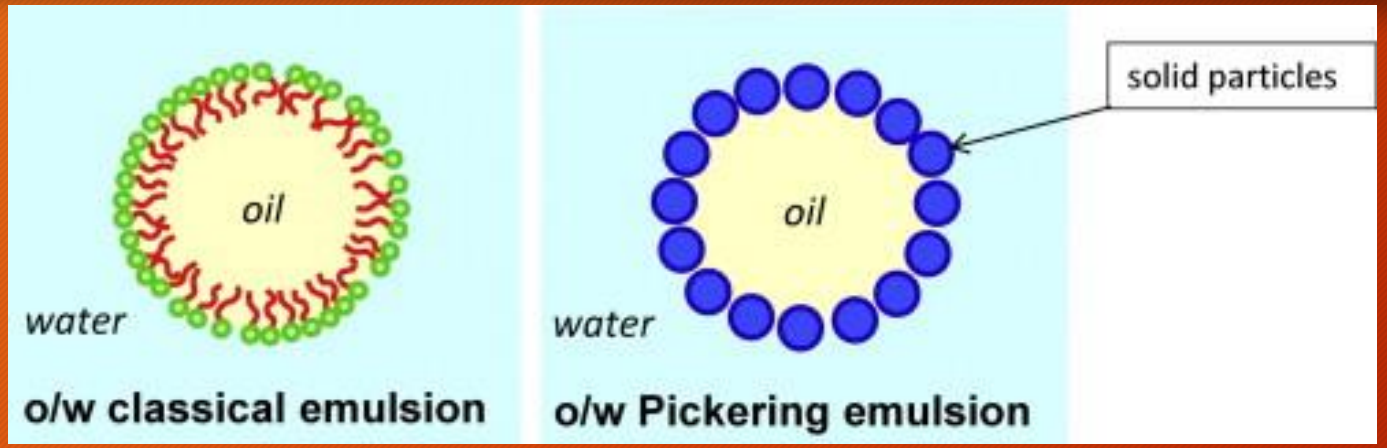
3. Nano-lipid carriers

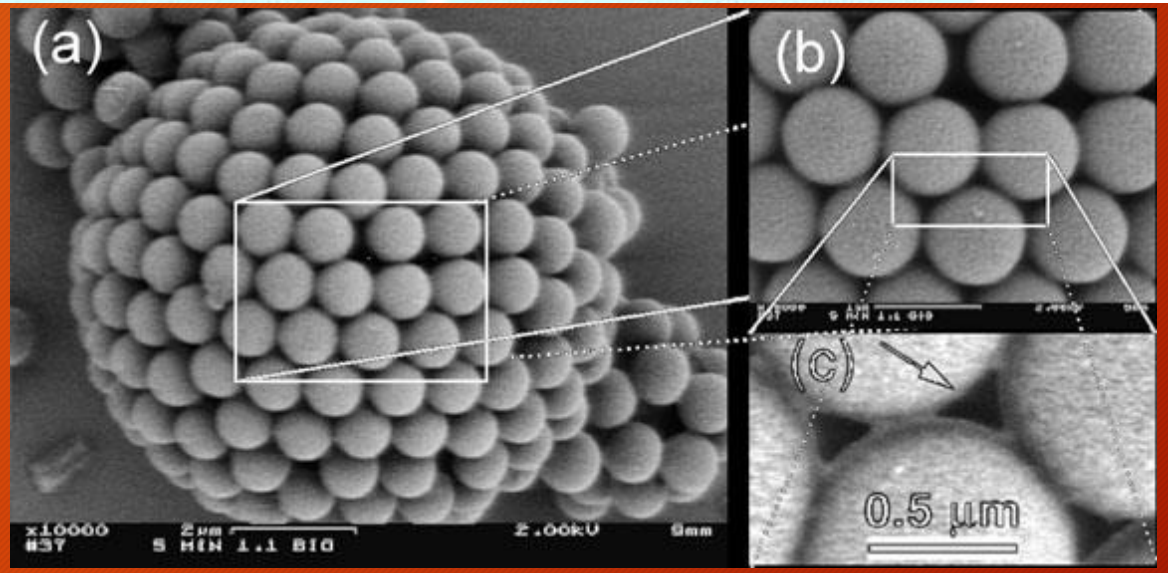
- **Solid Lipid Nanoparticles** (SLNs)
- **Nano-structured Lipid Carriers** (NLCs)
- **Smart Lipid nanocarriers**

Double emulsions *vs* single emulsions



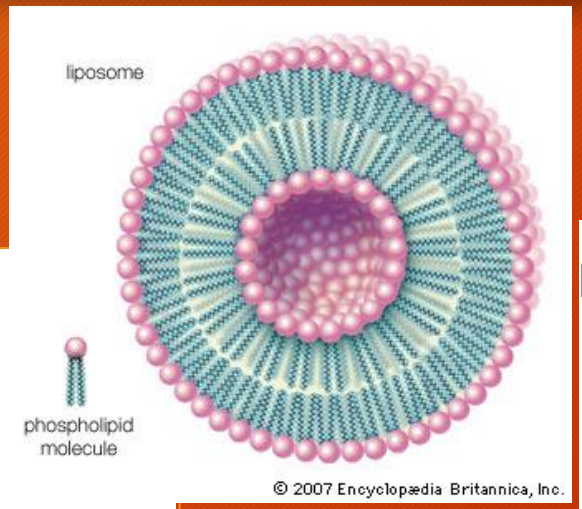
Pickering emulsions and colloidosomes

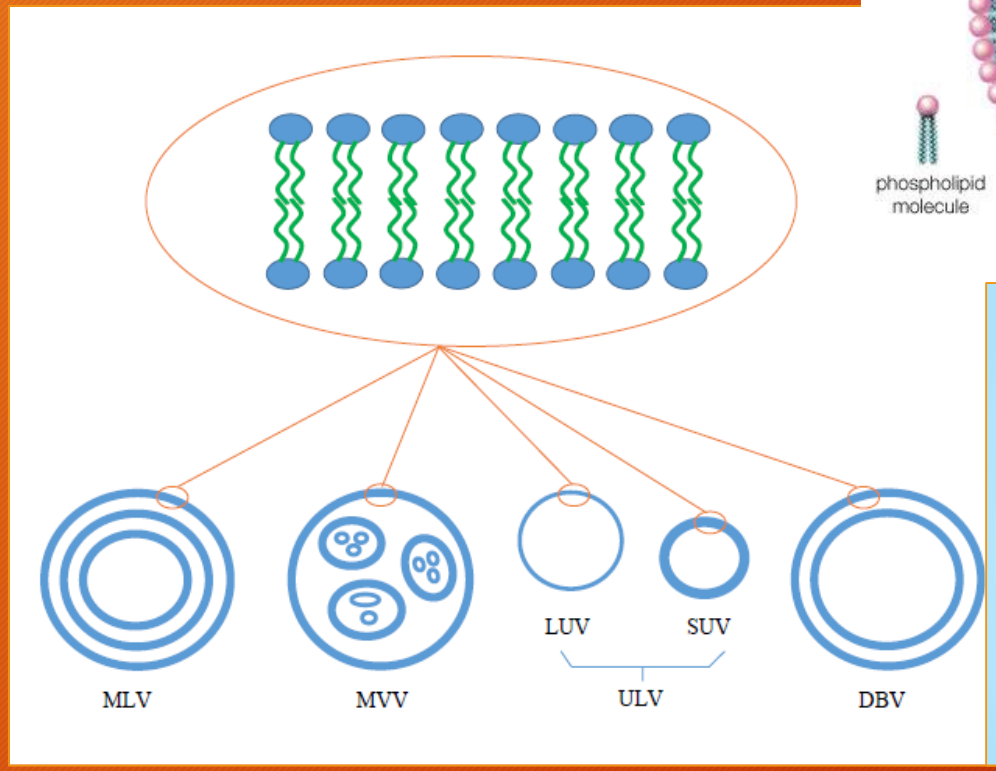


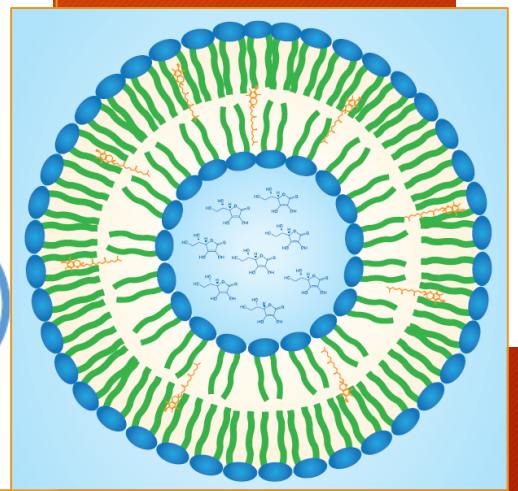


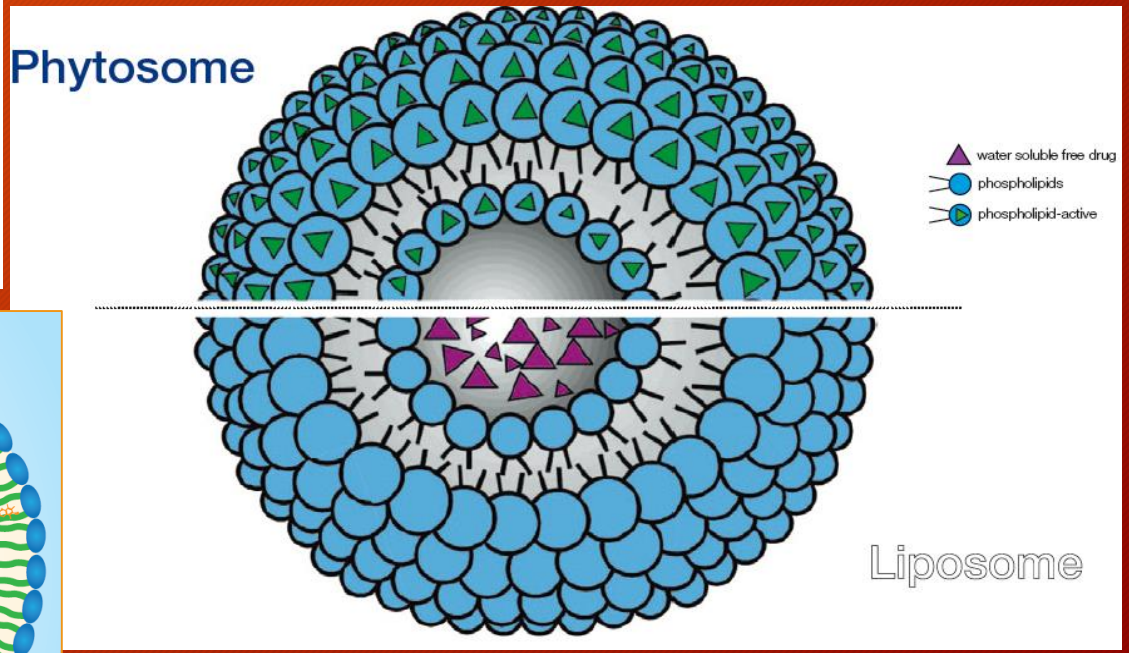
SEM images of a typical colloidosome showing (a) the assembly of colloidal particles on the interface of an emulsion droplet and (b) & (c) the pores (open space between particles) that control permeability

Nano-liposomes *vs* nano-phytosomes

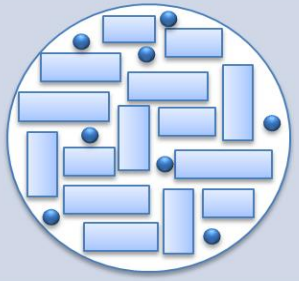
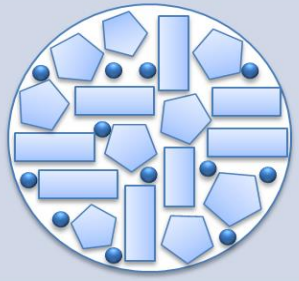
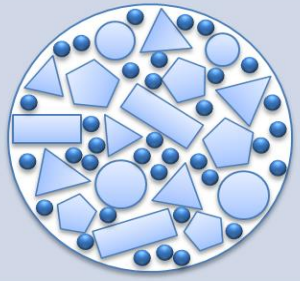


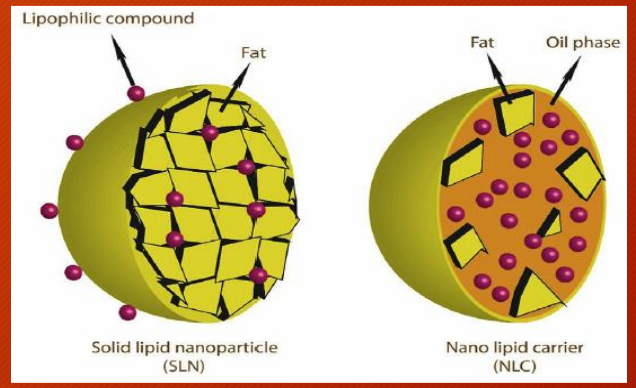


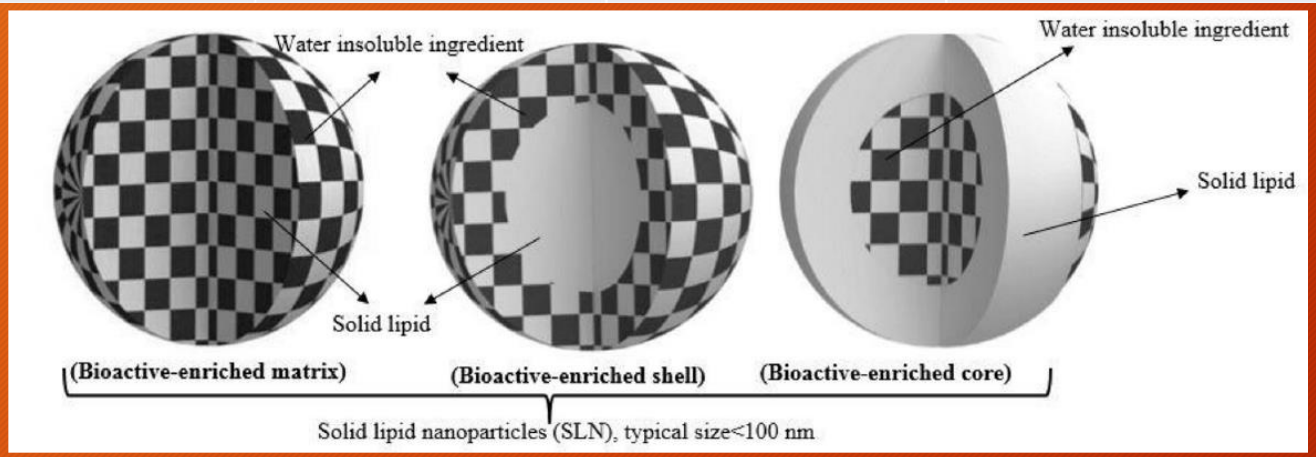


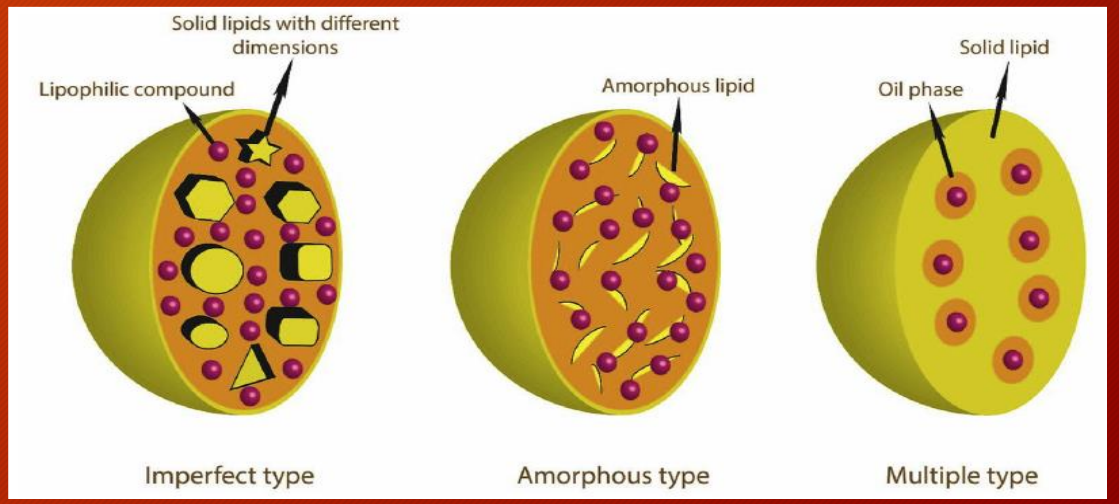


SLNs, NLCs and the latest generation smartLipids®

	SLN®	NLC®	smartLipids®
			
composition	1 solid lipid	1 solid lipid + 1 liquid lipid	up to 10 lipids (solid or solid + liquid)
structure	ordered	less ordered	highly chaotic
active loading	low	medium	high







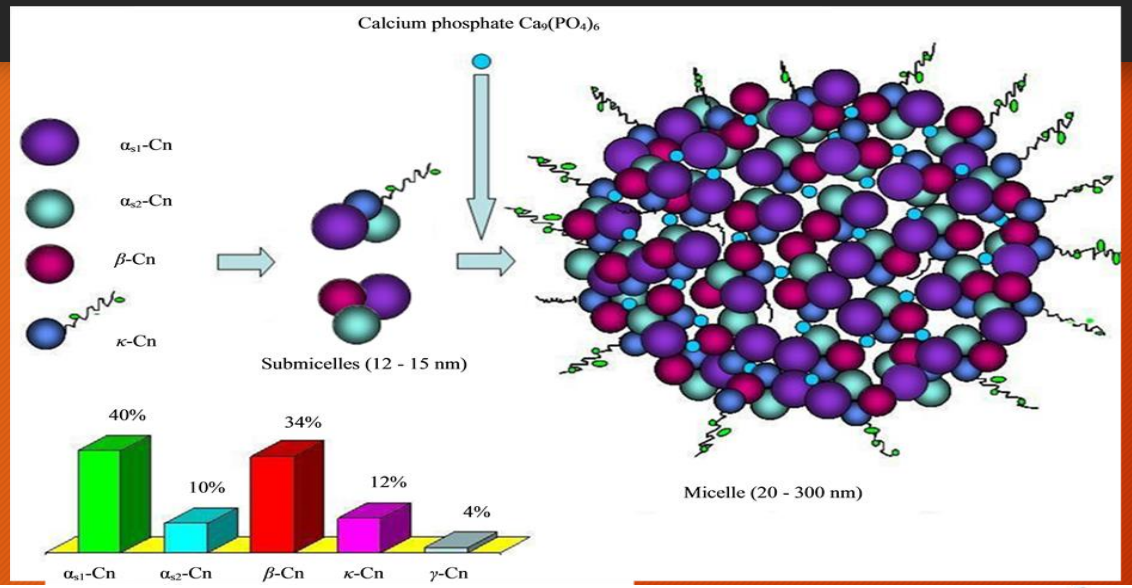
B. Nature-inspired nanocarriers

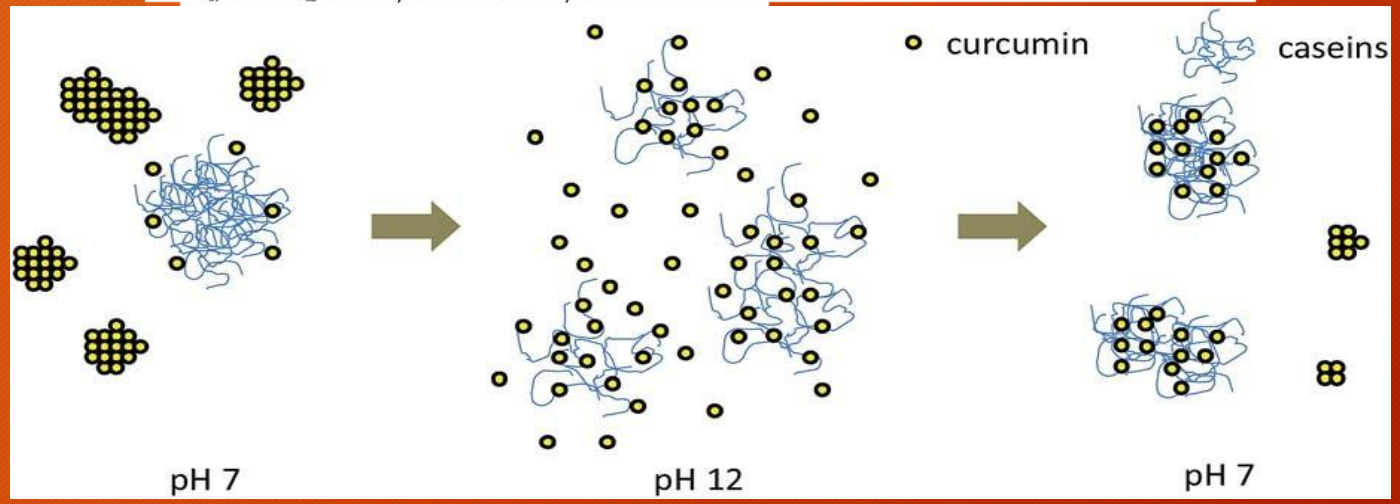
Caseins: Alpha, Beta, Gamma-caseins

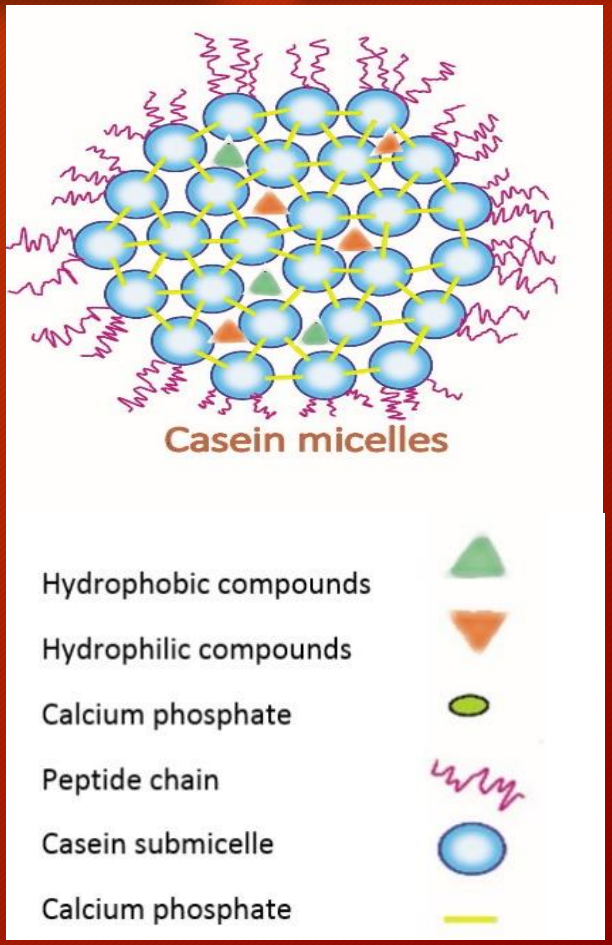
Cyclodextrins: Alpha, Beta, Gamma-cyclodextrins

Amylose: Single helix; Double helix

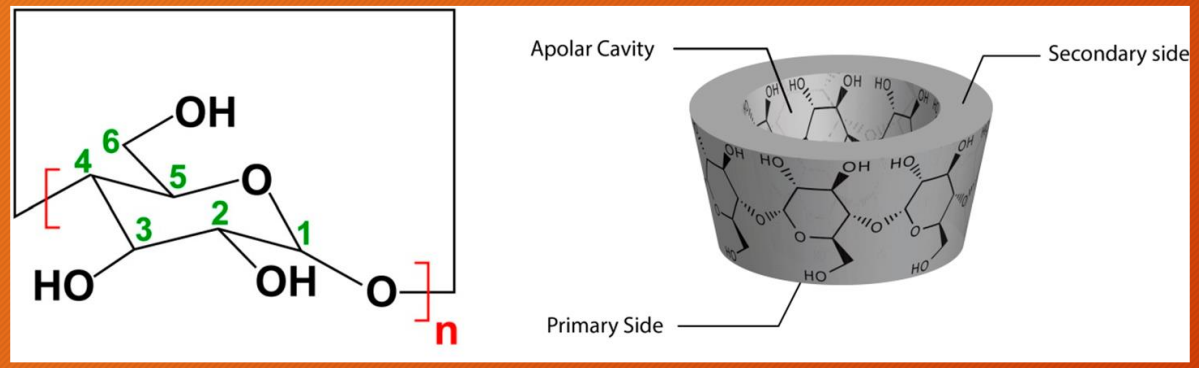
Casein nanocarriers

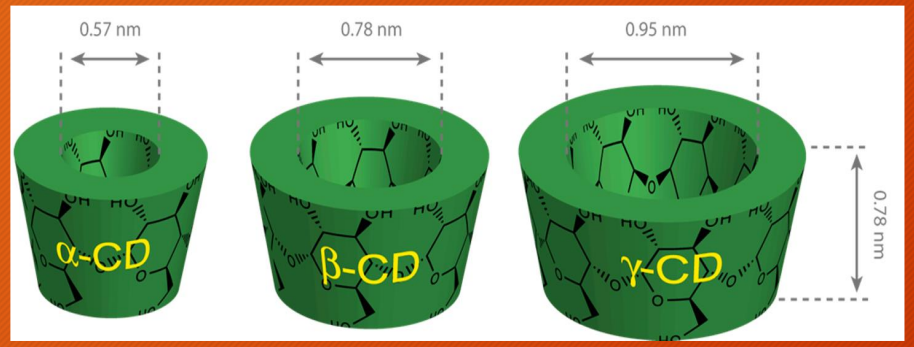


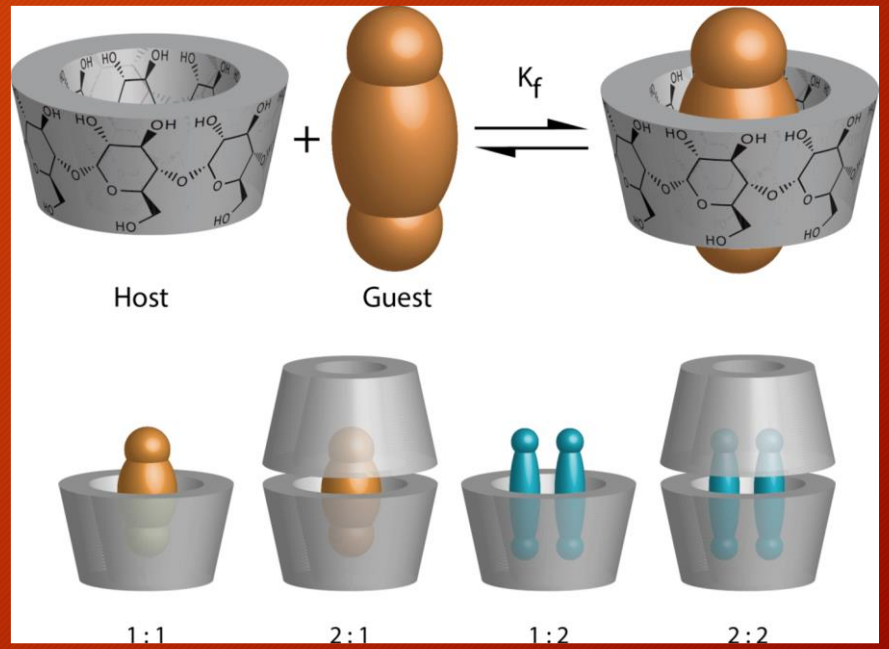




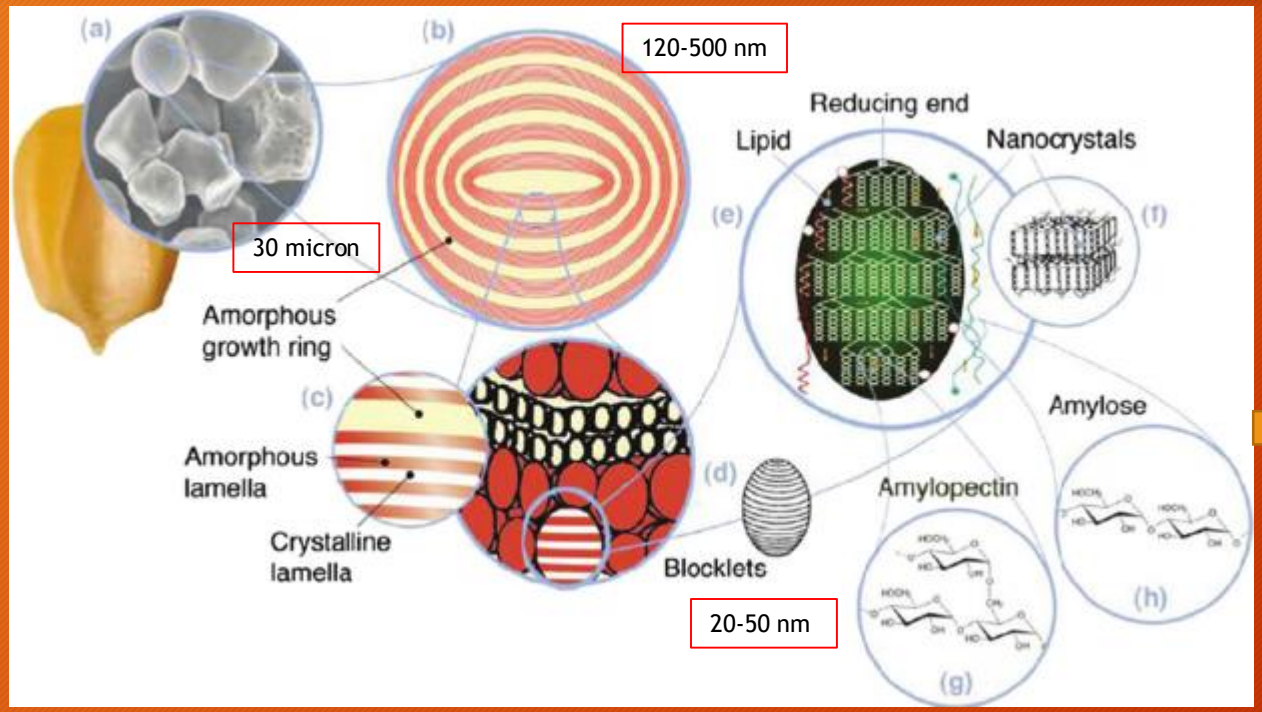
Cyclodextrins:α- (n = 6), β- (n = 7), and γ (n = 8)

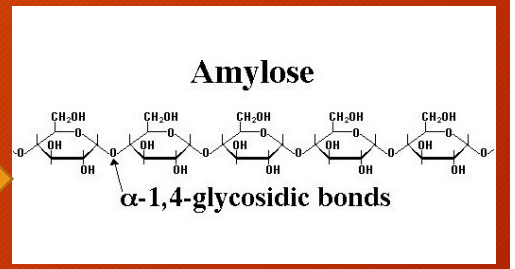


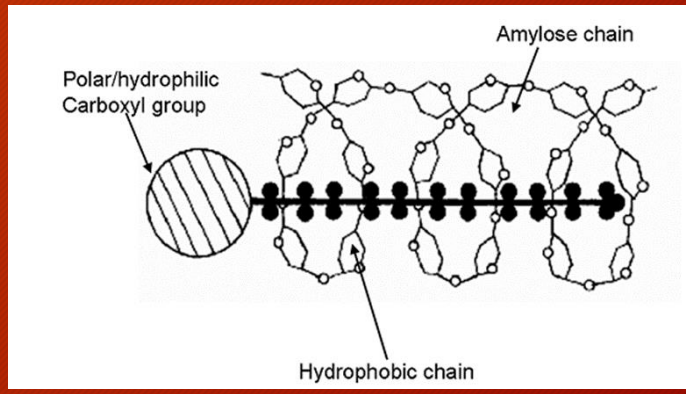


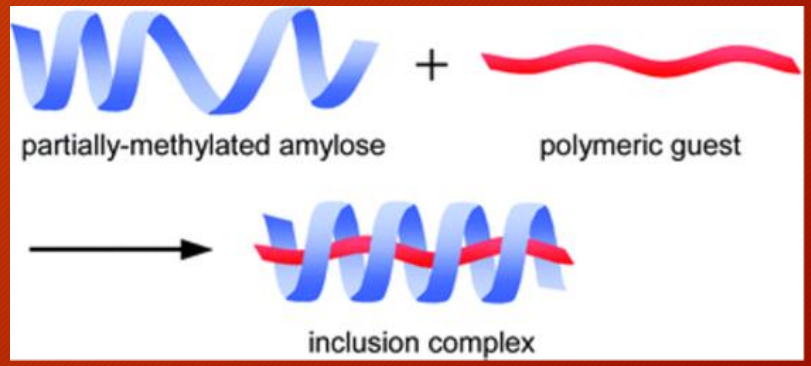


Amylose nanocarriers









C. Special equipment-based nanocarriers

Nanoencapsulation in the Food Industry

Nanoencapsulation of Food Ingredients by Specialized Equipment

Volume 3

Edited by

Seid Mahdi Jafari, Gorgan University of Agricultural Sciences and Natural resources, IRAN.

Nanoencapsulation of Food Ingredients by Specialized Equipment, a volume in the Nanoencapsulation in the Food Industry series, brings an overview of specialized developed equipment for the nanoencapsulation of food ingredients. Electro-spinning, electro-spraying, nano-spray dryer, micro/nano-fluidics systems, high pressure homogenizers/microfluidizers and sonication devices are some of the equipment analysed by the book.

Each chapter reviews the mechanisms of innovative devices for preparation of nanostructures, exploring the key factors in each device to control the efficiency of nanoencapsulation, revealing the morphologies and properties of nanoencapsulated bioactive ingredients produced by each equipment. Authored by a team of global experts in the fields of nano and microencapsulation of food, nutraceutical, and pharmaceutical ingredients, *Nanoencapsulation of Food Ingredients by Specialized Equipment* is of great value to those engaged in the various fields of nanoencapsulation.

Key Features

- Explores thoroughly the mechanisms of nanoencapsulation by specialized equipment
- Elucidates the key factors in each device to control the efficiency of nanoencapsulation
- Discusses the morphologies and properties of nanoencapsulated ingredients produced by each equipment

About the Editor

Prof. Seid Mahdi Jafari received his PhD from the University of Queensland (Australia), in 2006. He has been working on nanoencapsulation of food bioactives for the past 15 years. Now, as a full professor, he is an academic member of GUASNR (Iran). He has published more than 160 papers in top-ranked international journals and 30 book chapters along with editing 31 books with Elsevier. In November 2015, he was awarded as one of the top 1% world scientists by Thomson Reuters (Essential Scientific Indicators) in the field of Biological Sciences. Also in December 2017, he was selected as one of the top national researchers by the Iranian Ministry of Science, Research, and Technology. Recently in November 2018, he was awarded as one of the world's highly cited researchers by Clarivate Analytics (Web of Science).

ISBN 978-0-12-815671-1

ELSEVIER

ACADEMIC PRESS
An imprint of Elsevier
elsevier.com/books-and-journals

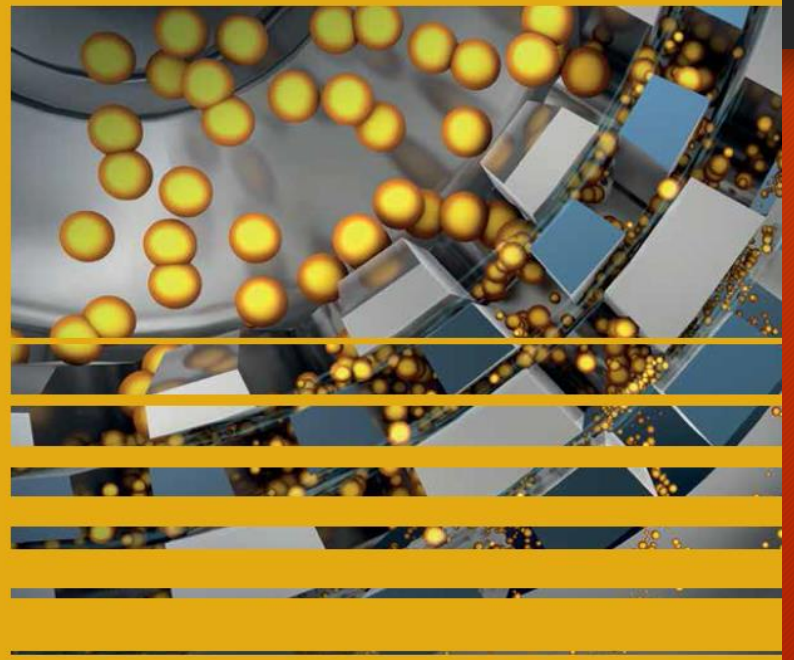
Jafari

Nanoencapsulation of Food Ingredients by Specialized Equipment

Volume 3

ACADEMIC PRESS

Nanoencapsulation in the Food Industry



Volume 3

Nanoencapsulation of Food Ingredients by Specialized Equipment

Edited by
Seid Mahdi Jafari

C. Special equipment-based nanocarriers

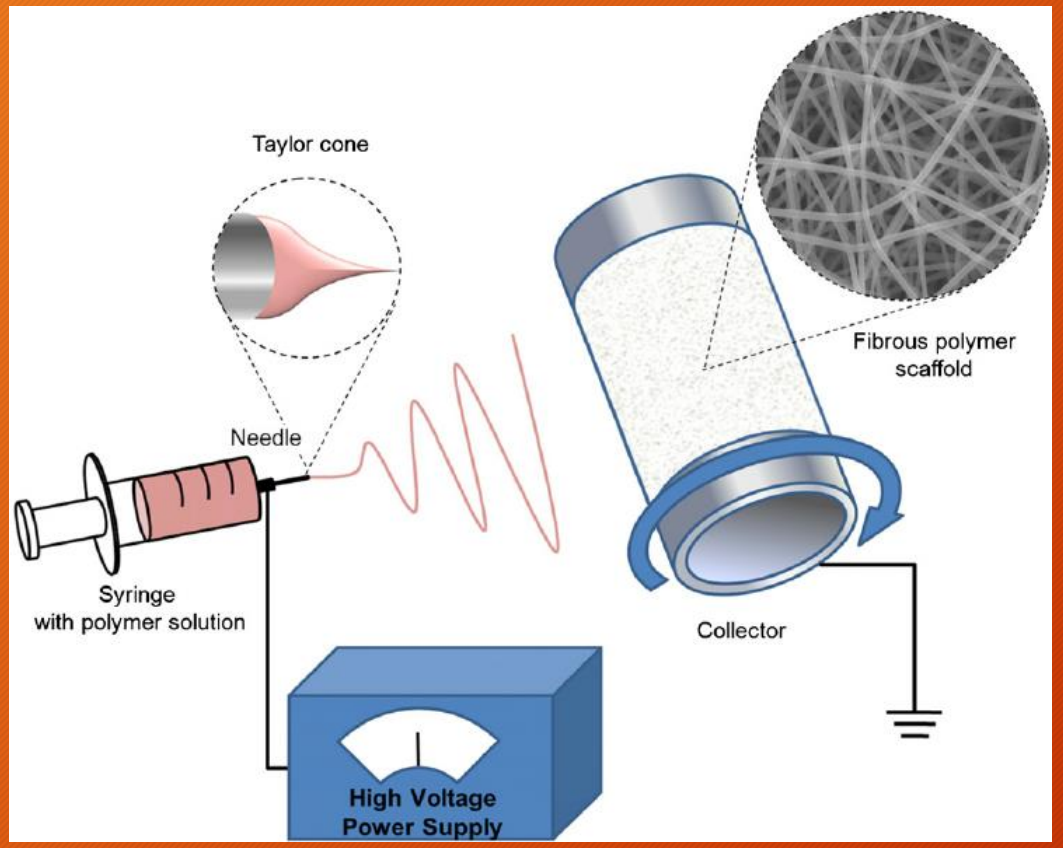
Electrospinning: Single injection nozzle; Coaxial double injection

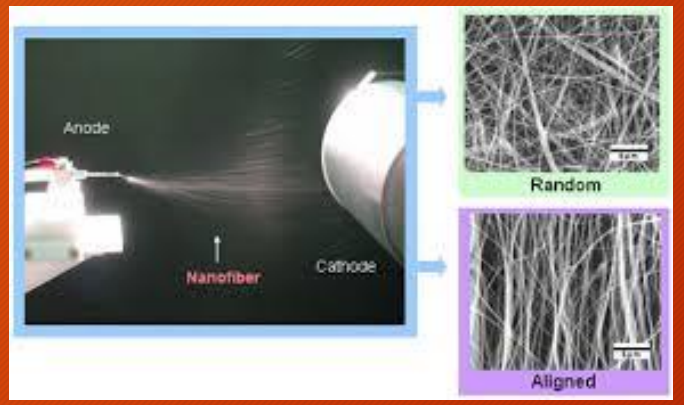
Electrospraying: Single injection nozzle; Coaxial double injection

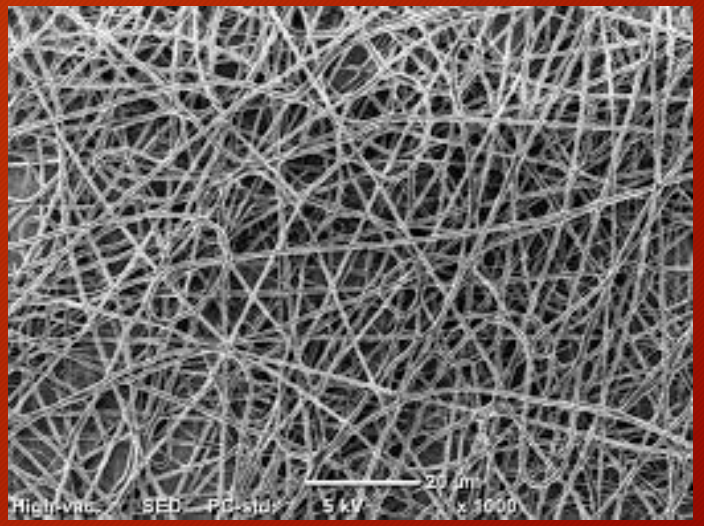
Nano-spray dryer

Micro/nanofluidics

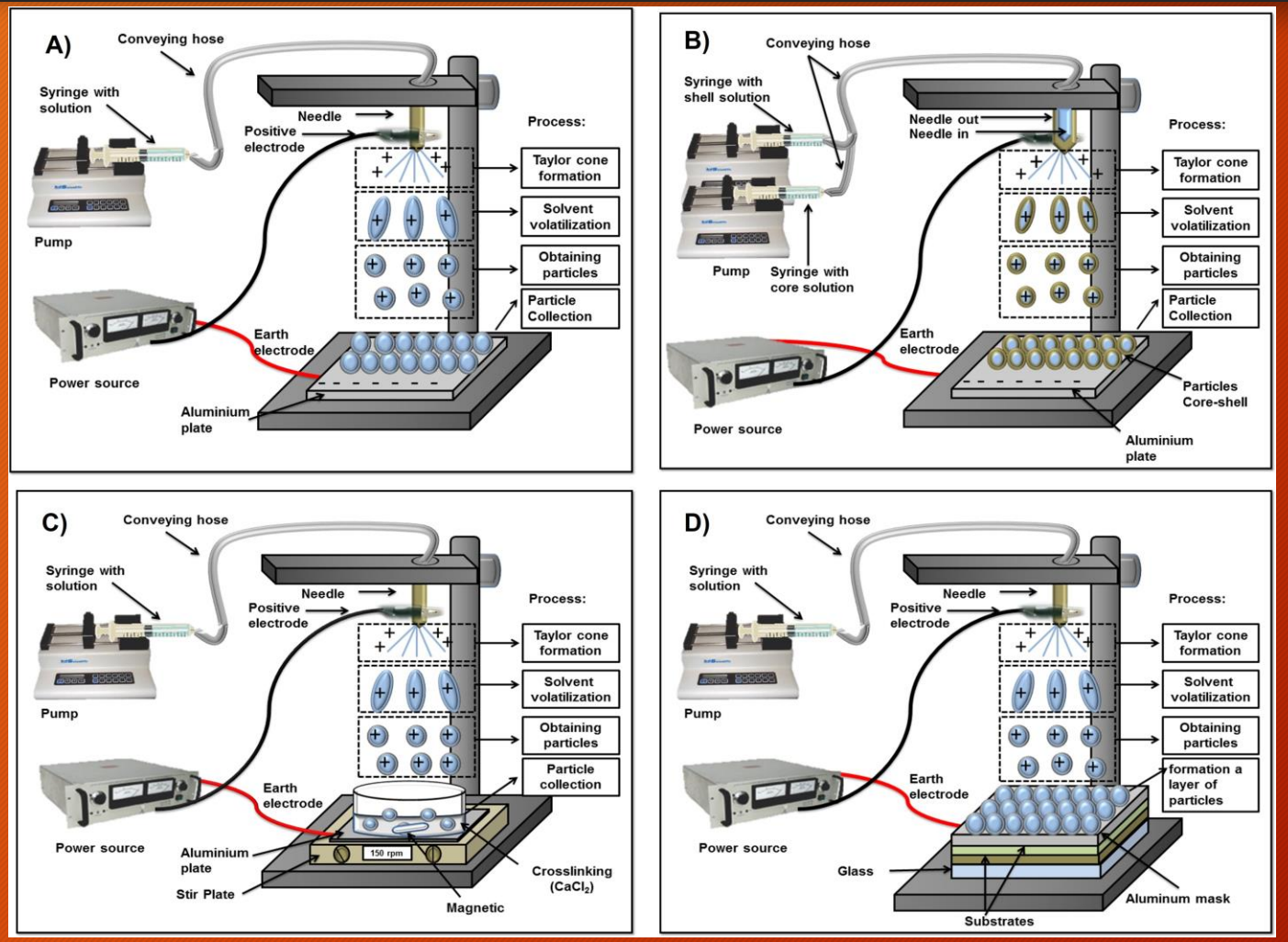
Nano-fibers produced by electro-spinning

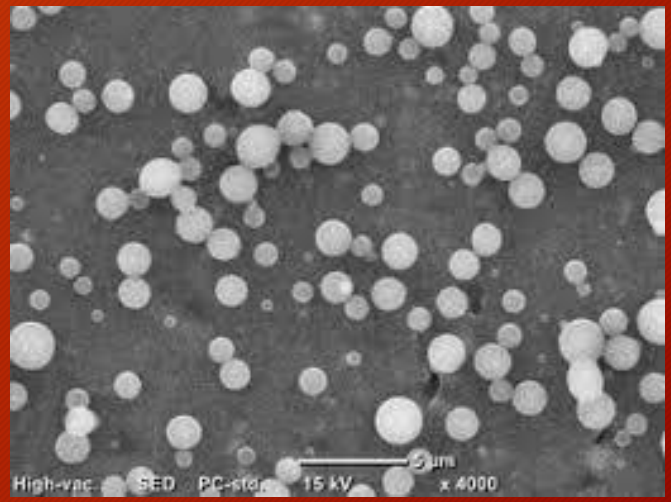




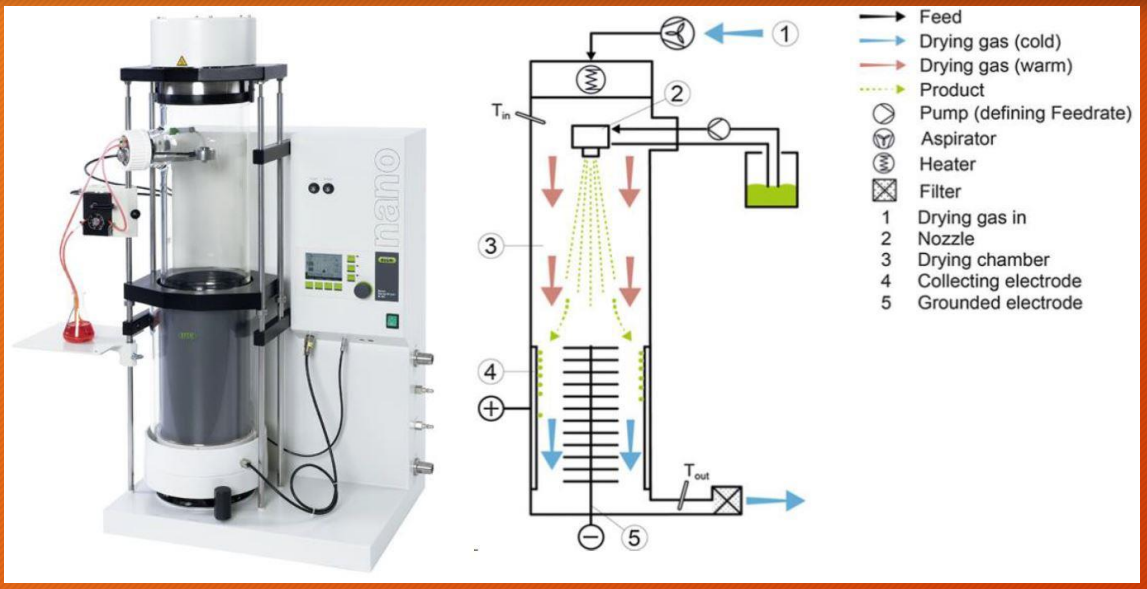


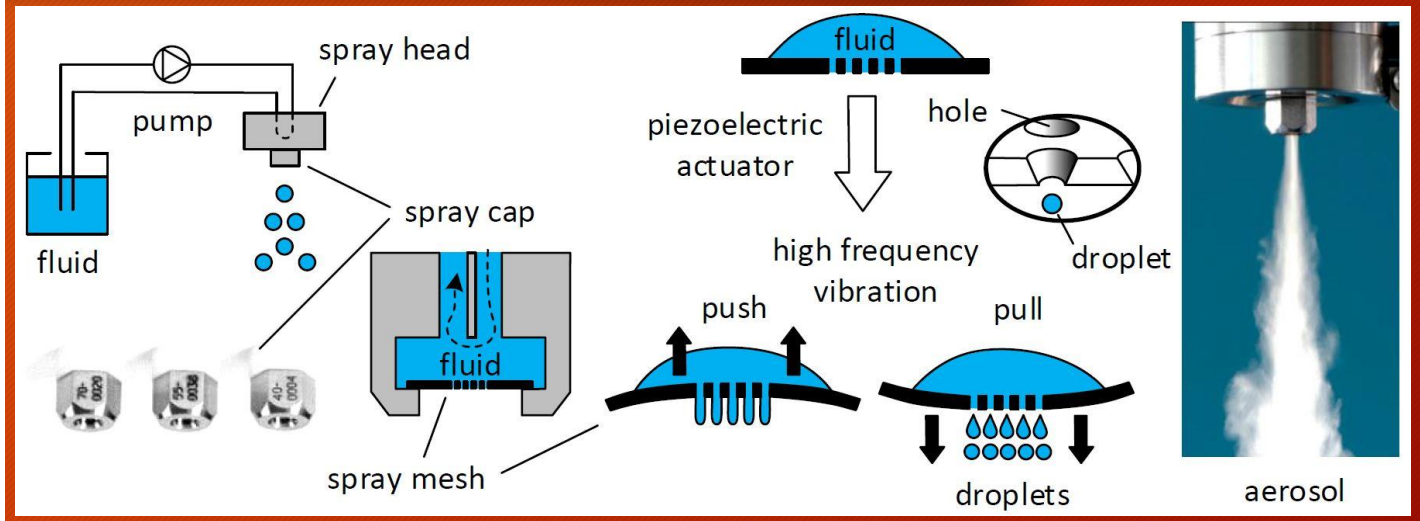
Nano-carriers prepared with electro-spraying

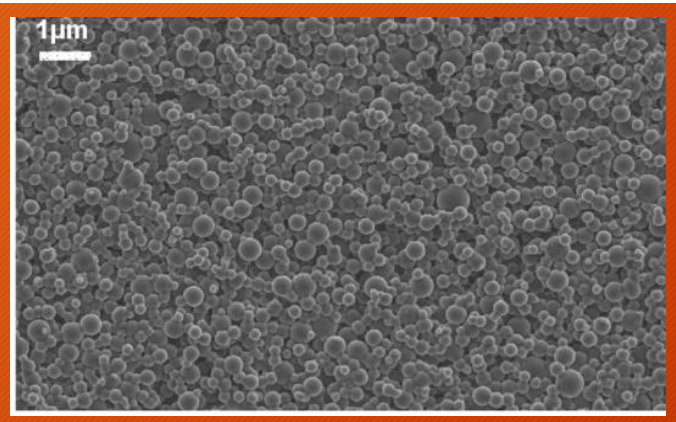


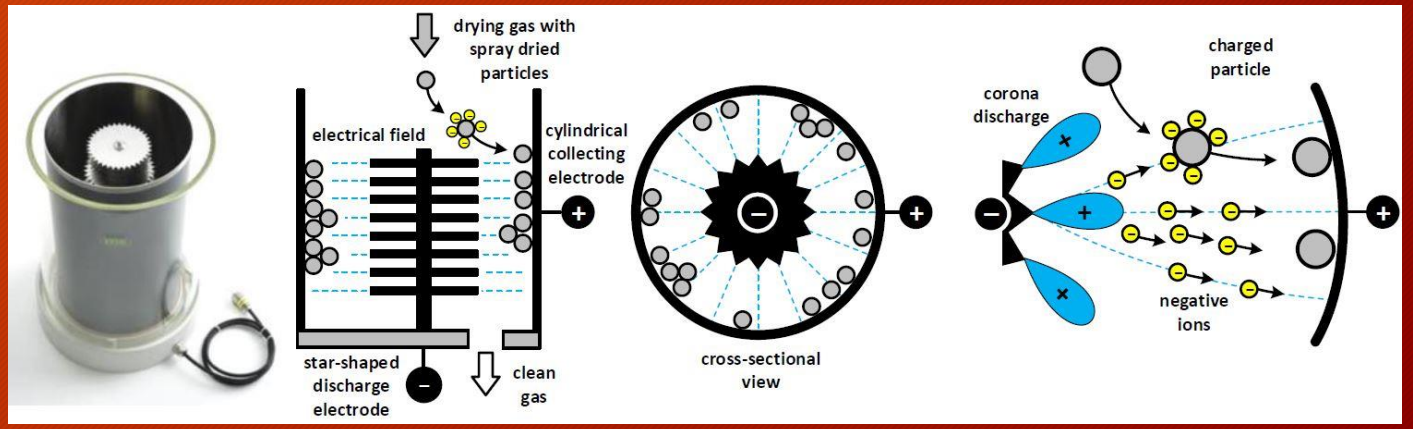


Nano Spray Dryer

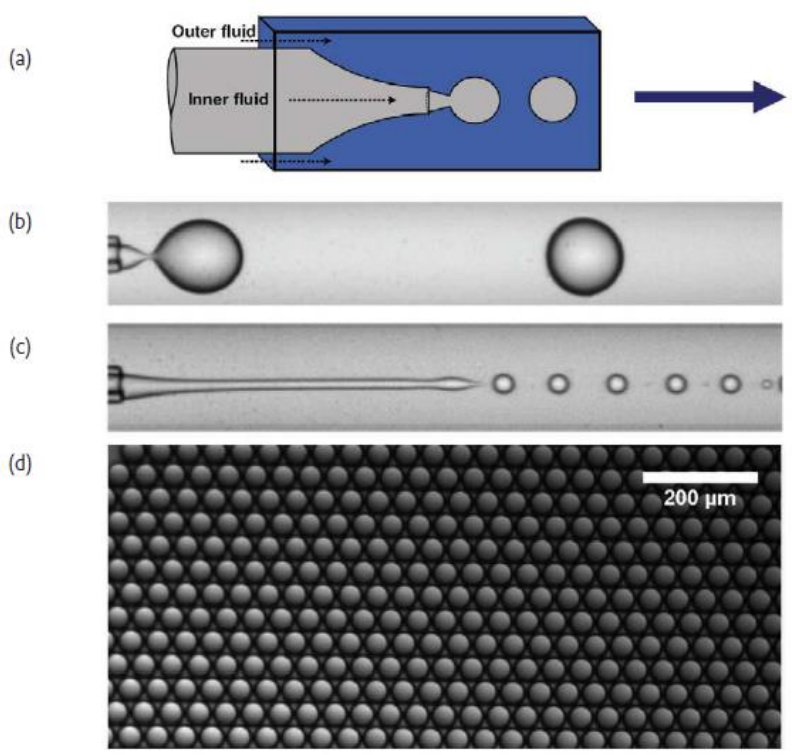




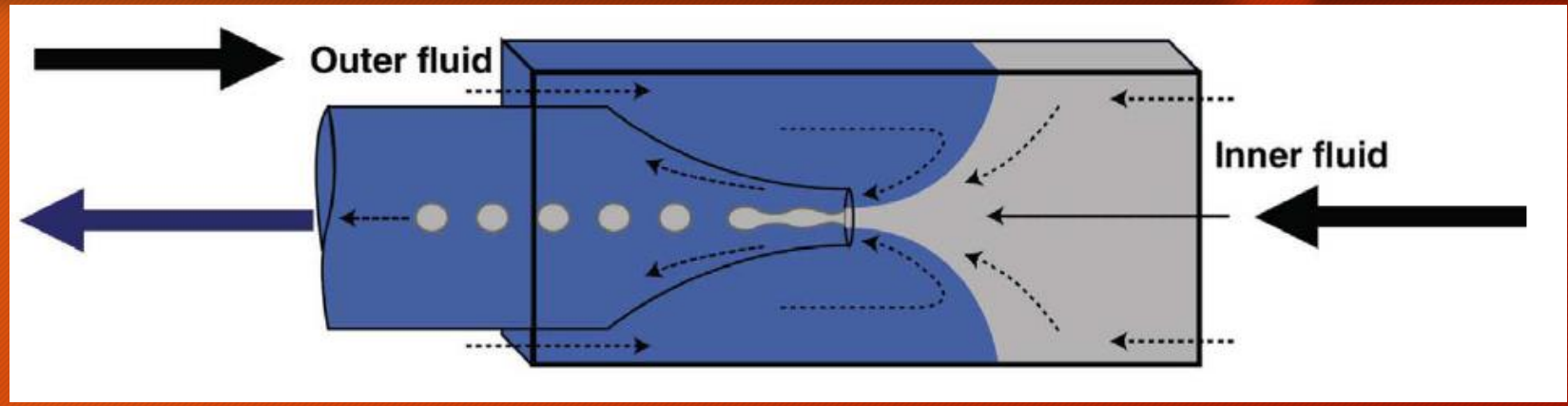




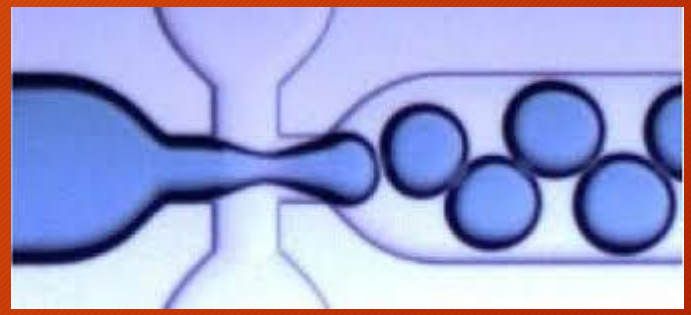
Micro/nano-fluidics



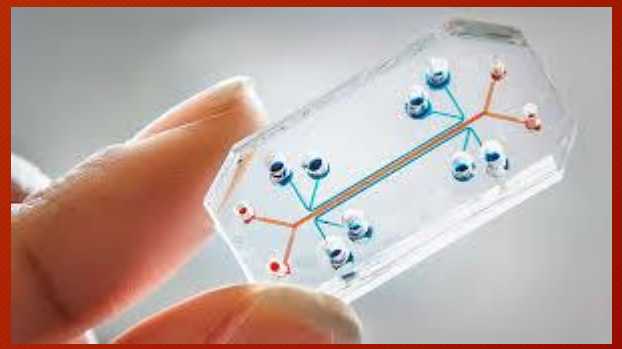
Coaxial flow of the two fluids



Flow-focusing (counter-flow) geometry



T-Junction geometry



Lab on a chip

D. Biopolymer-based nanocarriers

Nanoencapsulation in the Food Industry

Biopolymer Nanostructures for Food Encapsulation Purposes

Volume 1

Edited by

Seid Mahdi Jafari, Gorgan University of Agricultural Sciences and Natural resources, IRAN.

Biopolymer Nanostructures for Food Encapsulation Purposes, a volume in the *Nanoencapsulation in the Food Industry* series, guides readers on how to fabricate nanostructures/nanocarriers from different proteins and polysaccharides and apply them for food encapsulation purposes.

One of the main technologies for preparing nanoencapsulated bioactive ingredients and nutraceuticals is application of biopolymeric nanocarriers. This book covers recent and applied research in all disciplines of bioactive and nutraceutical delivery systems. All chapters emphasize original results relating to experimental, theoretical, formulation, and/or applications of nanostructured biopolymers.

Key Features

- Provides updated formulation and preparation of biopolymeric nanocarriers from proteins and polysaccharides
- Discloses knowledge and potential of biopolymer nanostructures for encapsulation
- Brings the novel applications of biopolymer nanostructures in developing bioactive delivery systems

About the Editor

Prof. Seid Mahdi Jafari received his PhD from the University of Queensland (Australia), in 2006. He has been working on nanoencapsulation of food bioactives for the past 15 years. Now, as a full Professor, he is an academic member of GUASNR (Iran). He has published more than 150 papers in top-ranked International Journals (h-index=35 in Scopus) and 30 book chapters along with editing 11 books with Elsevier. In November 2015, he was awarded as one of the top 1% world scientists by Thomson Reuters (Essential Scientific Indicators) in the field of Biological Sciences. Also in December 2017, he was selected as one of the top national researchers by the Iranian Ministry of Science, Research, and Technology. Recently in November 2018, he was awarded as one of the world highly cited researchers by Clarivate Analytics (Web of Science).

ELSEVIER

ACADEMIC PRESS
An imprint of Elsevier
elsevier.com/books-and-journals

ISBN 978-0-12-815663-6

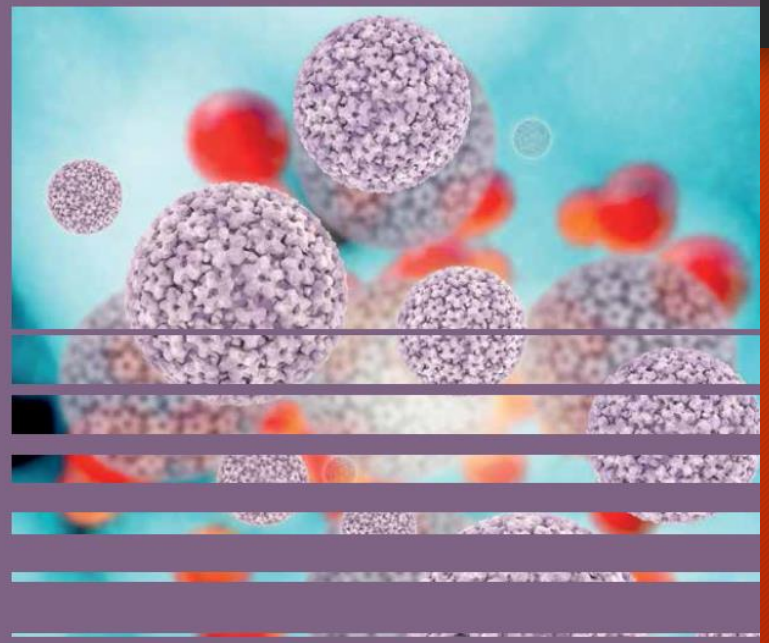
Jafari

Biopolymer Nanostructures for Food Encapsulation Purposes

Volume 1

ACADEMIC PRESS

Nanoencapsulation in the Food Industry



Volume 1

Biopolymer Nanostructures for Food Encapsulation Purposes

Edited by
Seid Mahdi Jafari

D. Biopolymer-based nanocarriers

1. Single biopolymer nanoparticles

- **Protein nanoparticles** made by desolvation: WPC, WPI, beta-lactoglobulin, BSA, Lactoferrin, SPI, Gliadin, Silk fibroins
- **Polysaccharide nanoparticles** made by precipitation: Chitosan, Starch, Cellulose, Gums

2. Complexd biopolymer nanoparticles

- **"Protein + Protein" nanostructures**
- **"Polysaccharide + Polysaccharide" nanostructures**
- **"Protein + Polysaccharide" nanostructures**

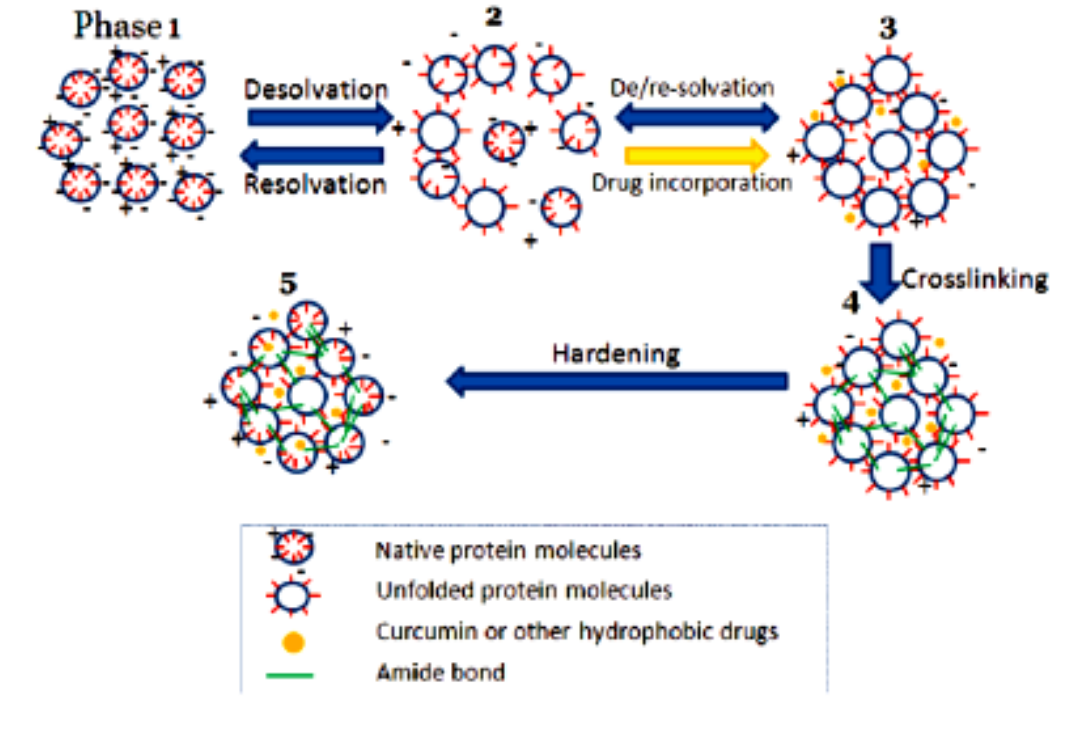
3. Nano-gels

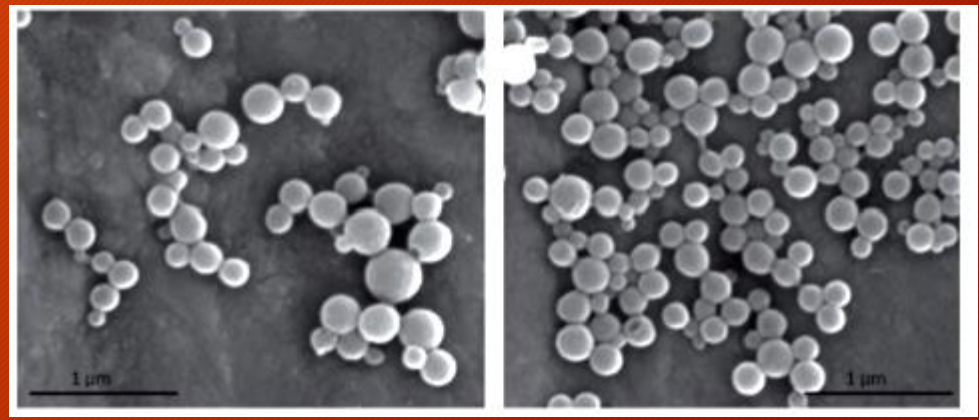
- **Nano-hydrogels**
- **Nano-organogels/oleogels**
- **Mixed nano-gels**

4. Nanotubes/nanofibrils

- **Protein nanotubes made with alpha-lactalbumin**
- **Protein nanofibrils made with beta-lactoglobulin**

Single biopolymer nanoparticles





Complexed biopolymer nanocarriers

= 0 at Ip
> 0 at pH<pI
< 0 at pH>pI

= 0 neutral
> 0 cationic
< 0 anionic

Similarly charged biopolymers (or a mixture containing a neutral partner)

+

Oppositely charged biopolymers

Complete electroneutrality

In the presence of excess amount of one partner troneutrality

Phase separation boundary

a

b

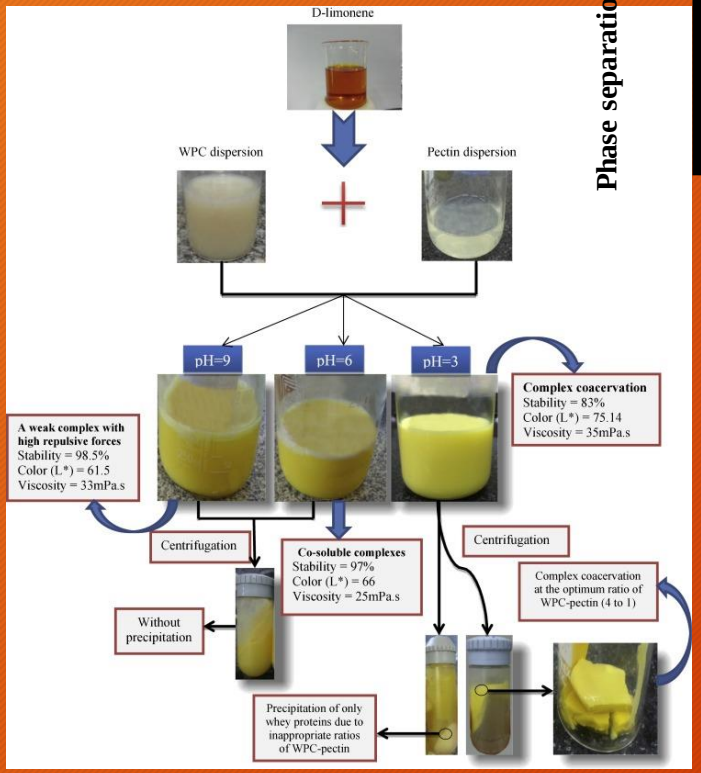
c

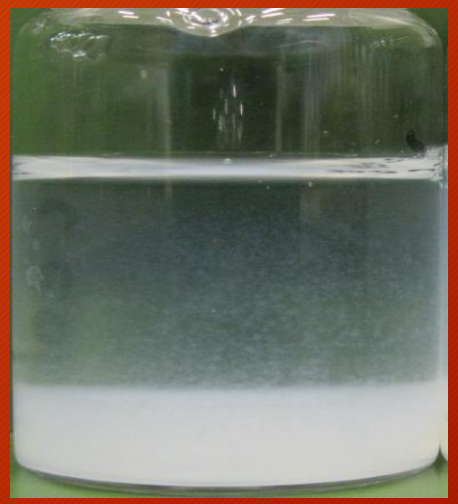
Segregative phase separation results in:
Two immiscible liquid phases

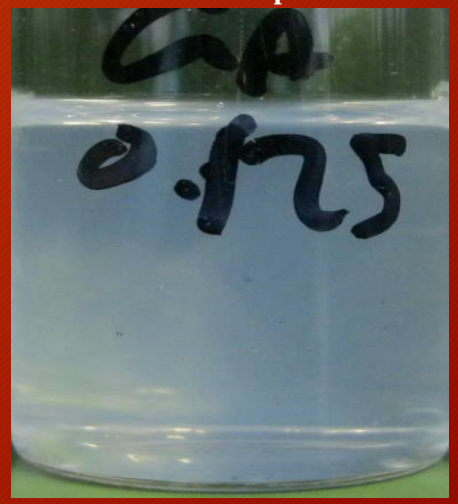
Associative phase separation results in:

Insoluble complexes

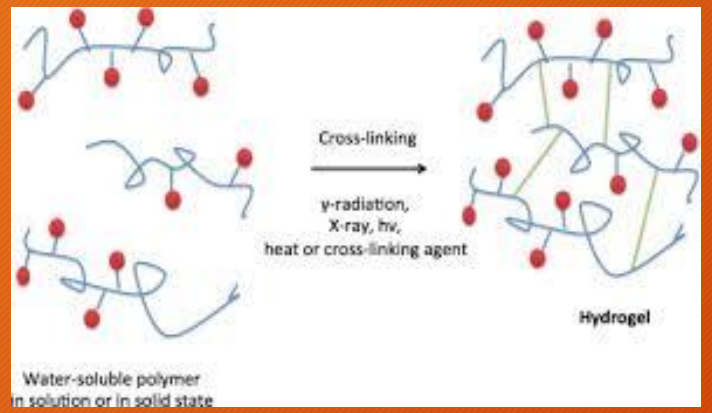
Soluble complexes

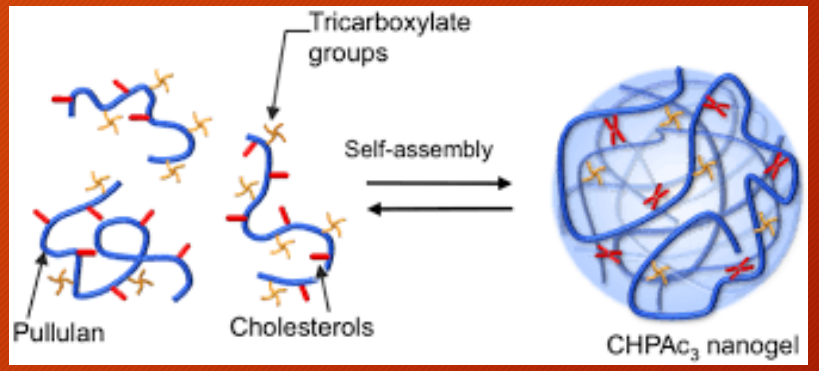


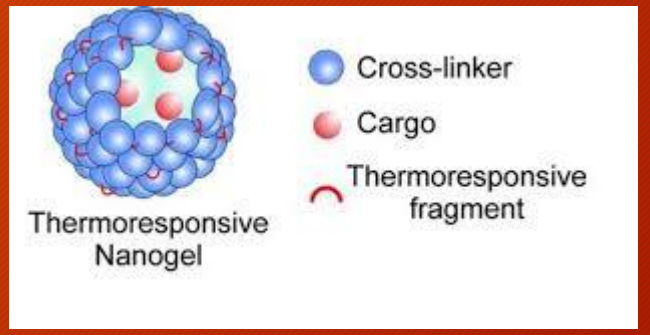


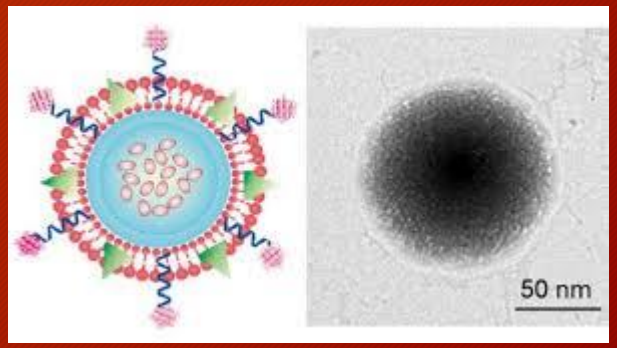


Nanogels

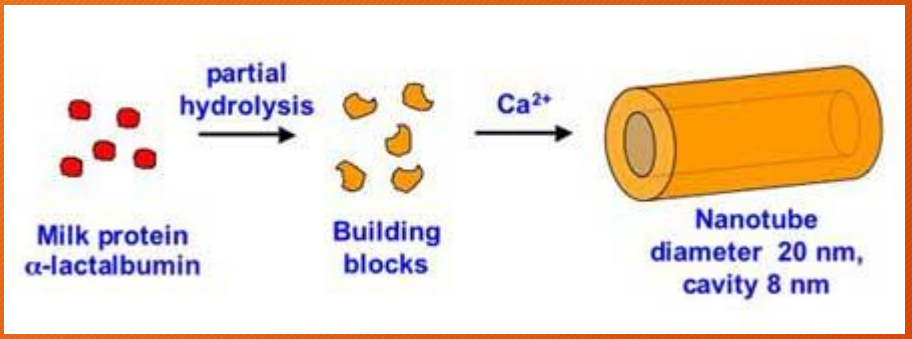

Cross-linking
γ-radiation,
X-ray, hν,
heat or cross-linking agent
Hydrogel
Water-soluble polymer
in solution or in solid state

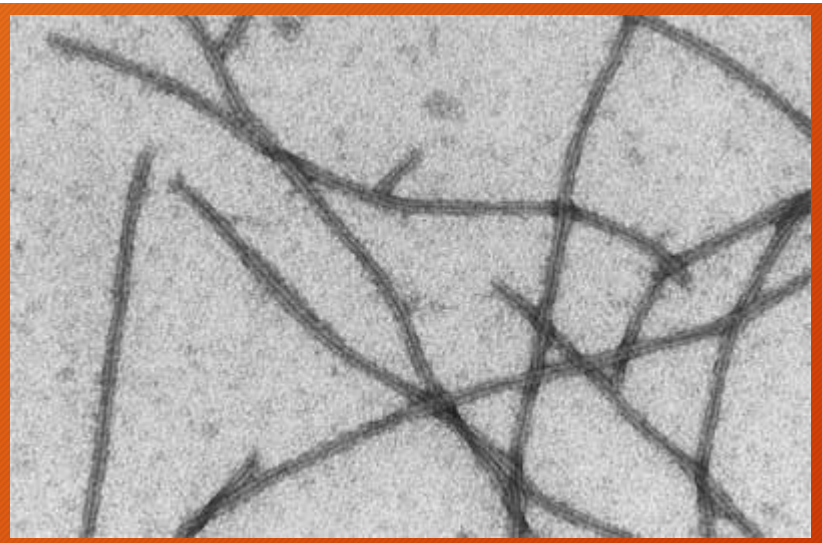

Tricarboxylate
groups
Self-assembly
Pullulan
Cholesterols
CHPAc3 nanogel


Thermoresponsive
Nanogel
Cross-linker
Cargo
Thermoresponsive
fragment

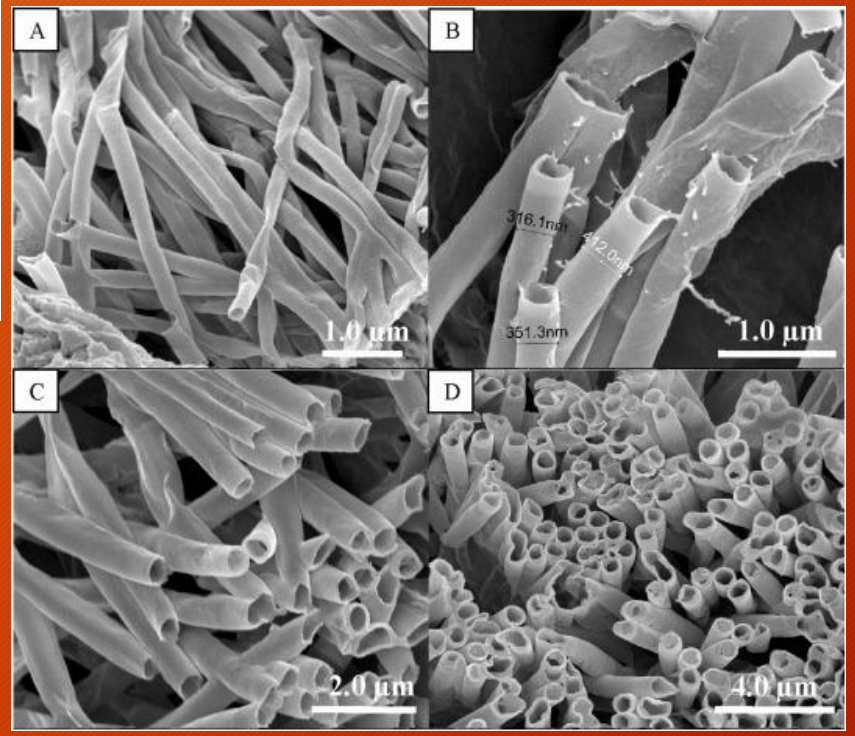

50 nm

Nanotubes

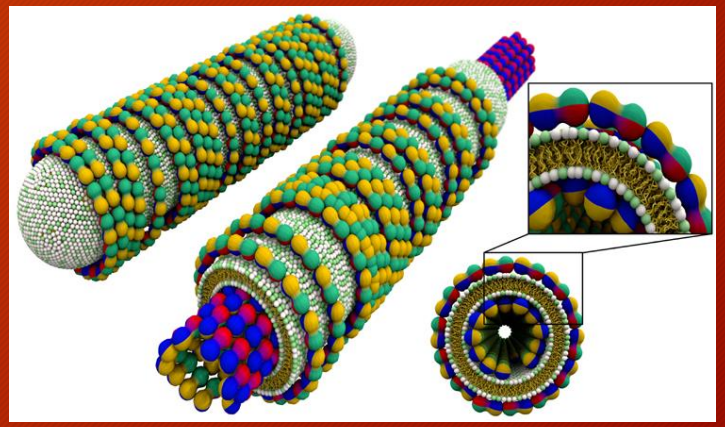




α-lactalbumin nanotubes



BSA + Alginate nanotubes

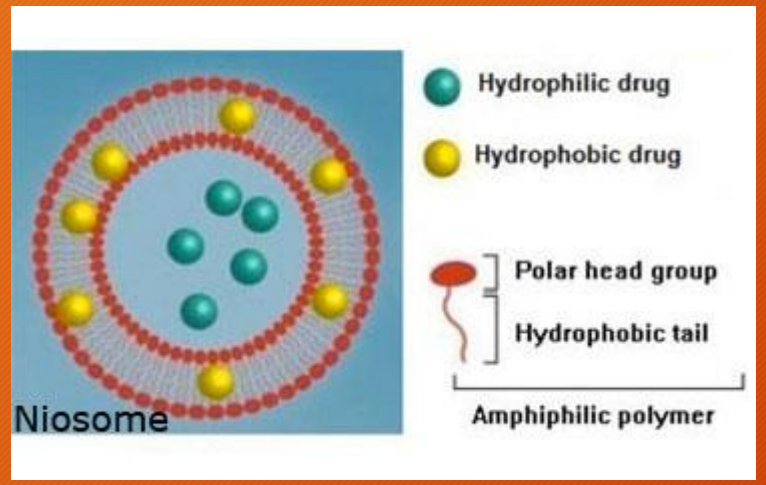


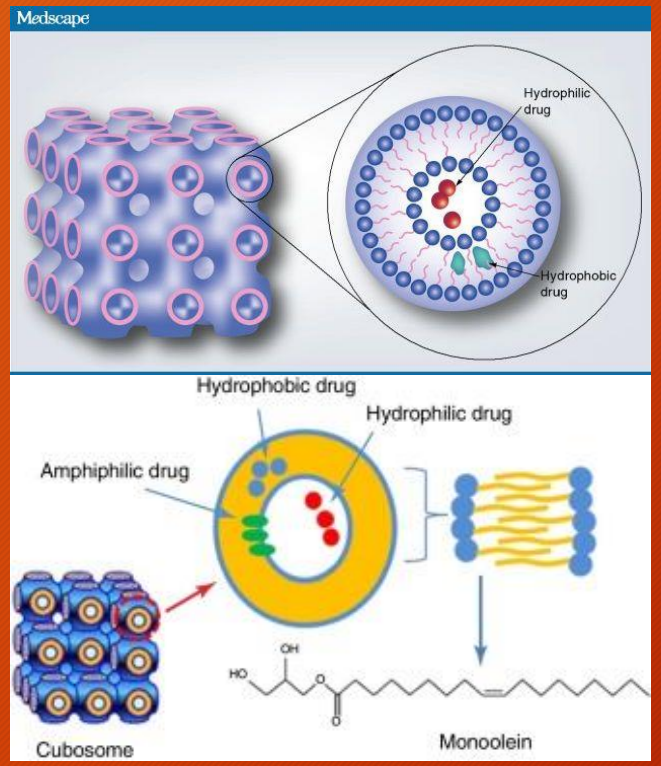
Protein-phospholipid nanotubes

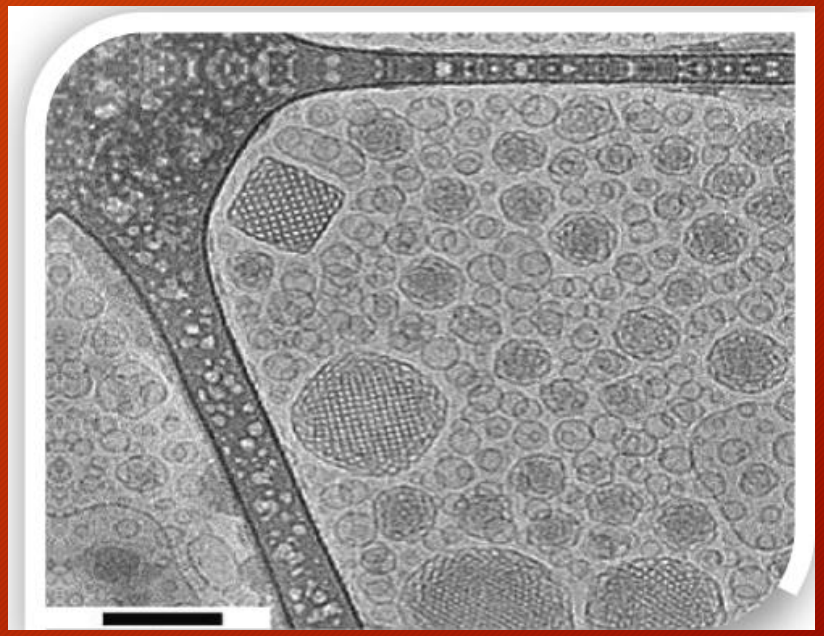
E. Miscellaneous nanocarriers

1. Chemical polymer nanoparticles	• Poly-d,l-lactide (PLA) • PEG • PLGA • Poly-γ-glutamic acid (PGA) • Poly-capro-lactone acid (PCA) • Dendrimers
2. Nano-structured surfactants	• Niosomes • Cubosomes • Microemulsions
3. Inorganic nanocarriers	• Magnetic nanoparticles • Silica nanoparticles • Carbon nanotubes • Quantum dots • Gold nanoparticles
4. Nano-crystals	• Bioactives within nano-crystals made with cellulose, starch, ... • Bioactive crystals within other nanocarriers

Nano-structured surfactants: Niosomes *vs* cubosomes

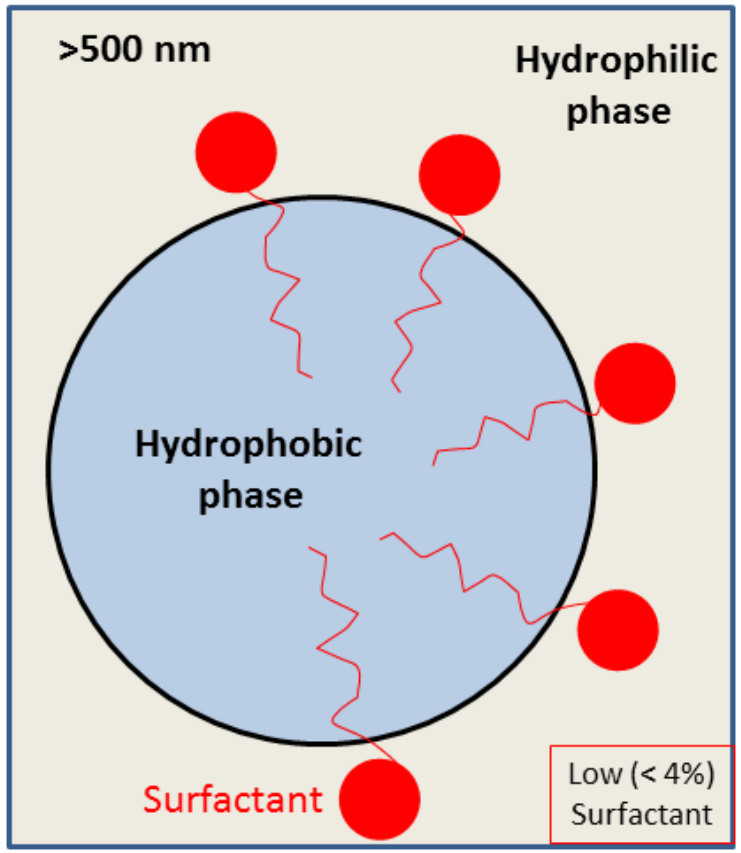






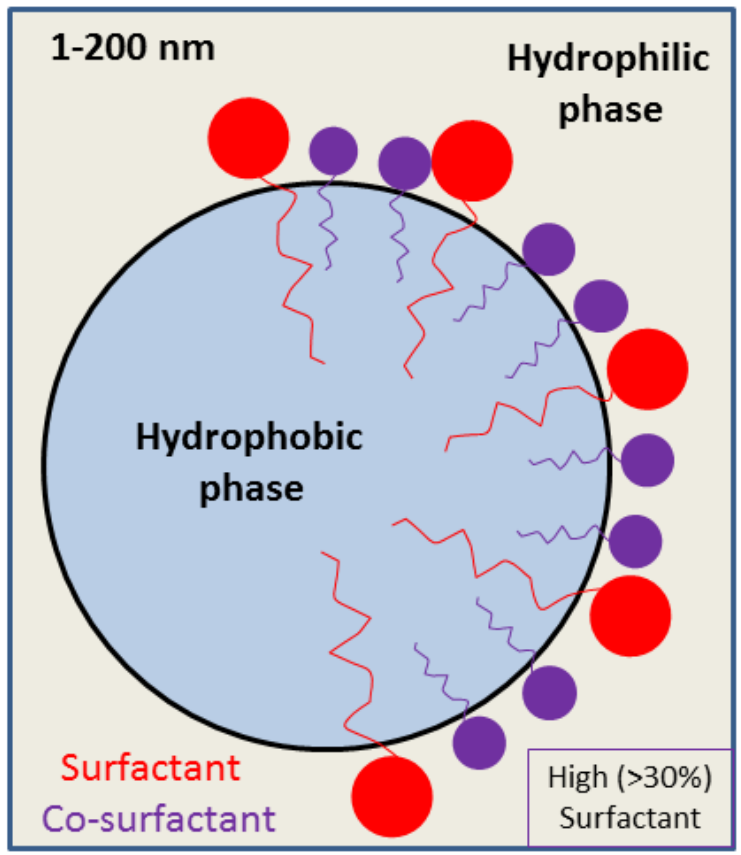
Nano-structured surfactants: Microemulsions

Macro-Emulsion

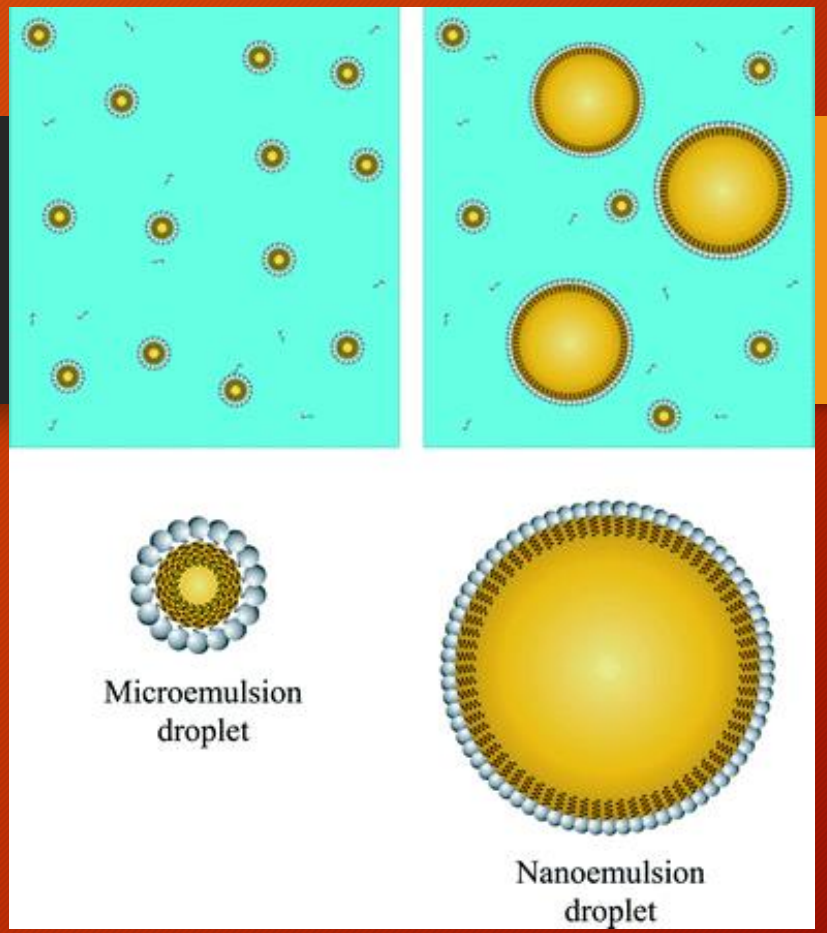


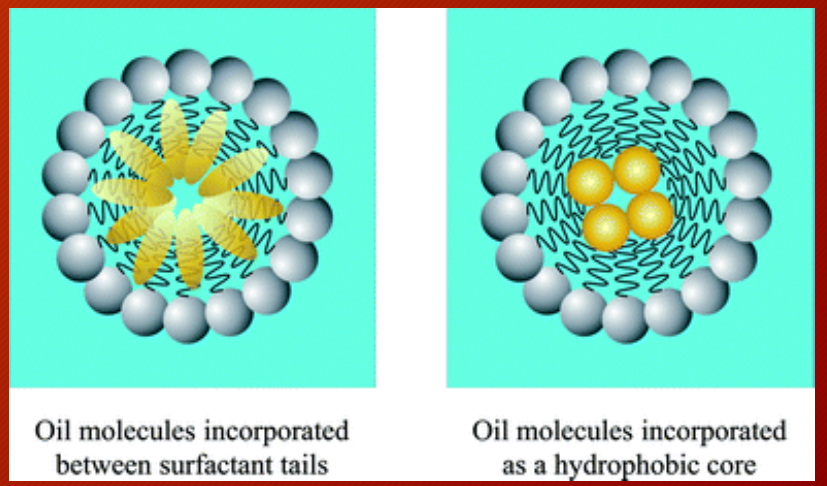
Requires input of energy

Micro-Emulsion

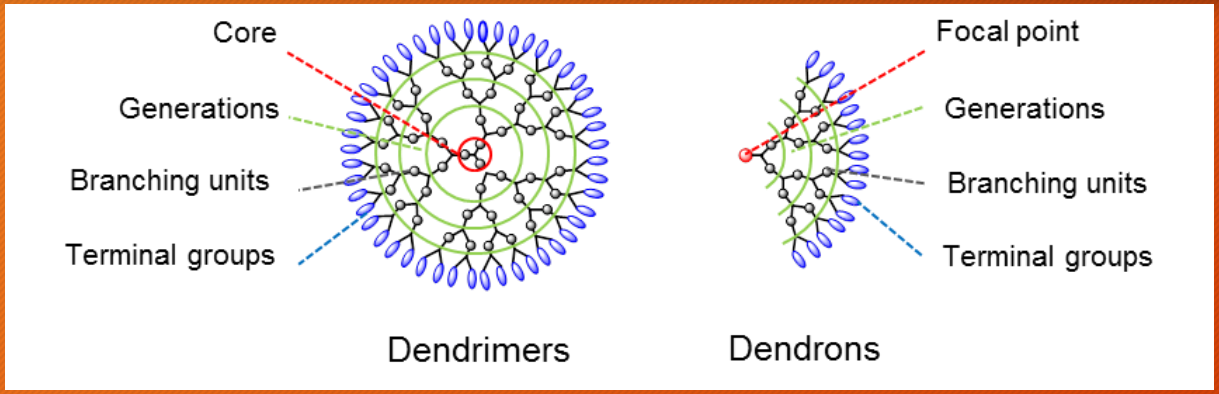


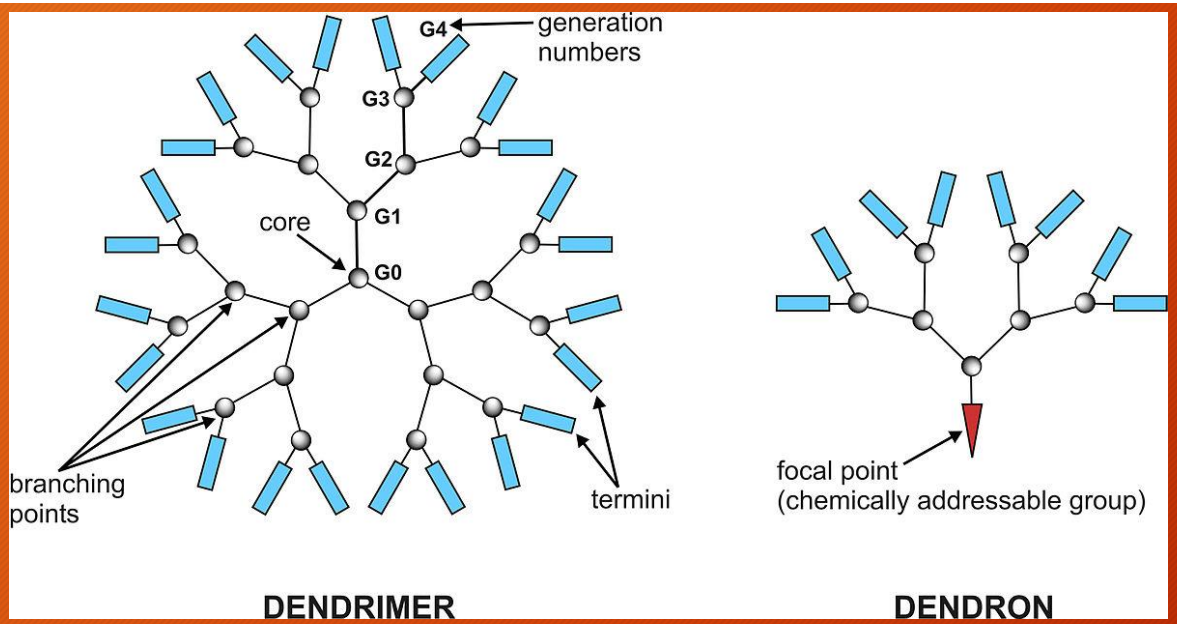
Forms Spontaneously – No energy

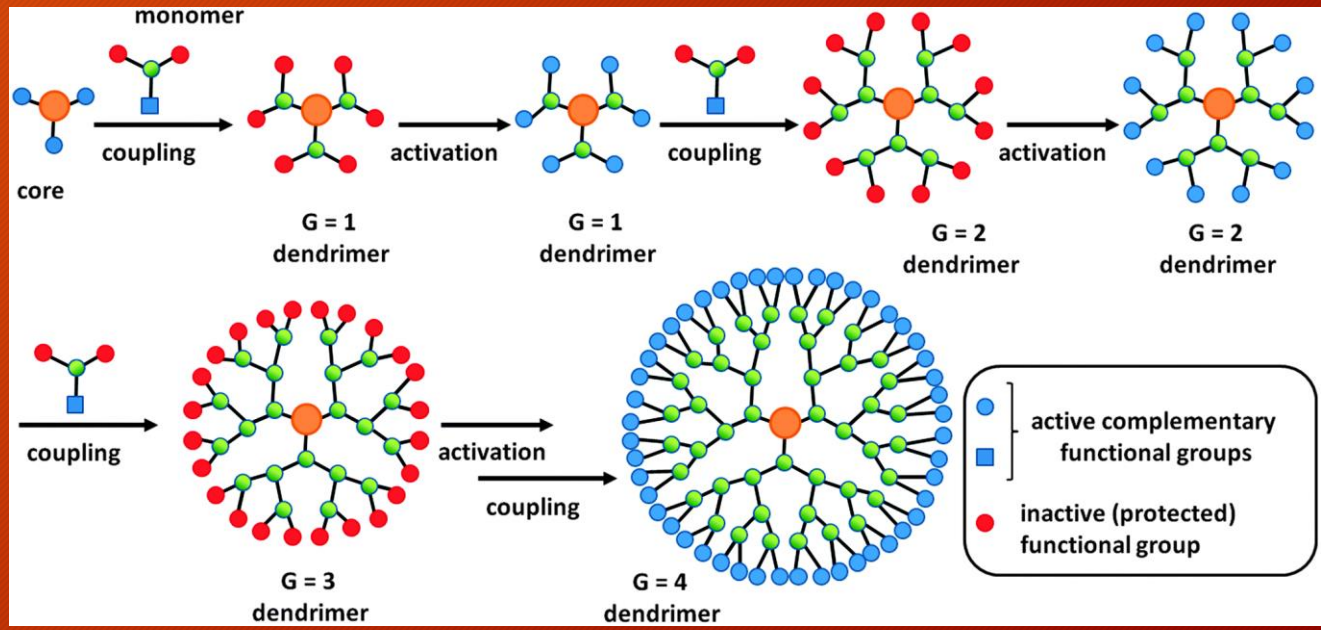




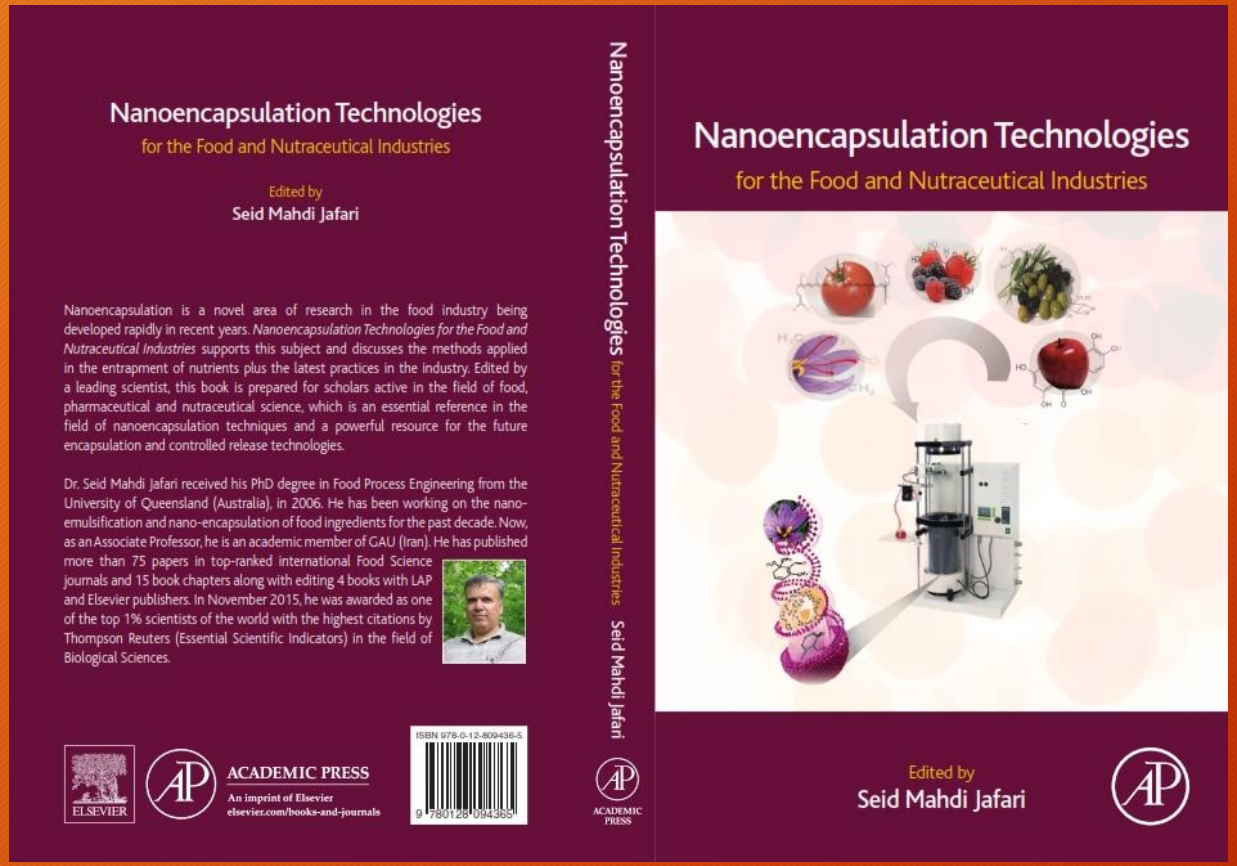
Nano-structured chemical polymers: Dendrimers

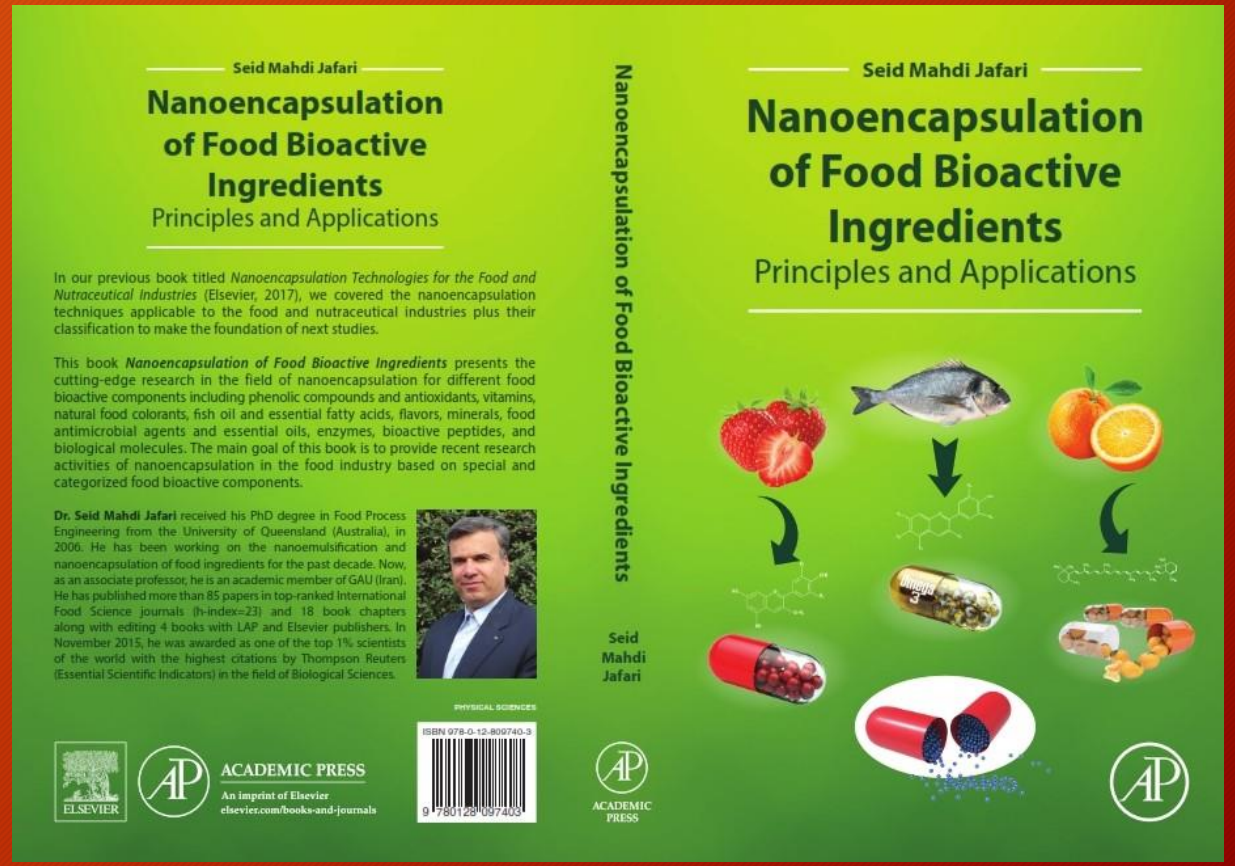






Suggested references





Nanoemulsions

Formulation, Applications, and Characterization

Edited by Seid Mahdi Jafari and David Julian McClements

Nanoemulsions: Formulation, Applications, and Characterization provides detailed information on the production, application, and characterization of nanoemulsions as presented by scientists and engineers from the food, agrochemical, chemical, cosmetics, and pharmaceutical areas. Those involved in the nutraceutical, pharmaceutical, and cosmetic industries will find this a useful reference, as it presents state-of-the art information related to the different preparation and formulation methods of nanoemulsions and their application in a broad range of fields and products. This book highlights recent research that clearly demonstrates the advantages of nanoemulsions over conventional emulsions for many commercial applications, making it a timely resource.

Key Features

- Summarizes general aspects of nanoemulsions and their formulation
- Provides detailed information on the production, application, and characterization of nanoemulsions
- Highlights existing and novel applications of nanoemulsions in functional foods, nutraceutical products, pharmaceuticals, agrochemicals, and cosmetic formulations
- Explains the preparation of nanoemulsions by both low- and high-energy methods

Seid Mahdi Jafari is an Associate Professor in the Department of Food Materials and Process Design Engineering at Gorgan University of Agricultural Sciences and Natural Resources, Iran. He has been working on the nanoemulsification and nanoencapsulation of food ingredients for the past decade and he has been awarded as one of the top 1% scientists of the world with the highest citations by Thomson Reuters (Essential Scientific Indicators) in the field of Biological Sciences.

David Julian McClements is a Distinguished Professor in the Department of Food Science at the University of Massachusetts, Amherst, USA. He is one of the most highly cited authors in the food and agricultural area, and is internationally recognized for his research on the fabrication and application of nanoemulsions and other types of colloidal delivery systems.

ELSEVIER

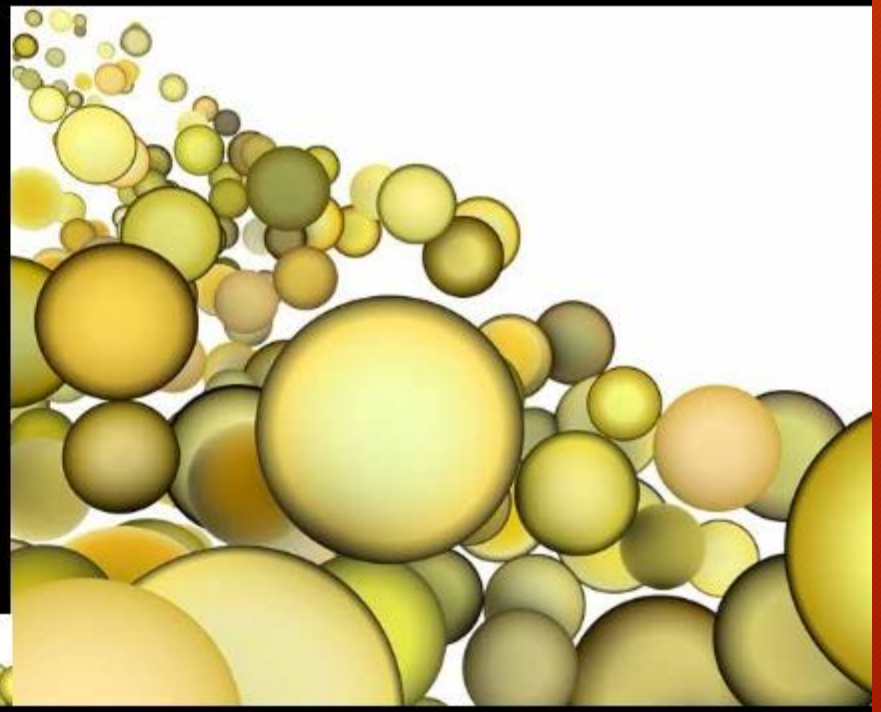
ACADEMIC PRESS
An imprint of Elsevier
elsevier.com/books-and-journals

ISBN 978-0-12-811838-2

S M Jafari
D J McClements

Nanoemulsions

Nanoemulsions
Formulation, Applications, and Characterization



ACADEMIC PRESS

Edited by
Seid Mahdi Jafari
David Julian McClements

Thanks for your attention

Dr. Seid Mahdi Jafari

Department of Food Materials and Process Design Engineering
Faculty of Food Science and Technology
University of Agricultural Sciences and Natural Resources, Gorgan, IRAN

017-32426432 **www.gau.ac.ir** **Smjafari@gau.ac.ir**